Indian Wind Power

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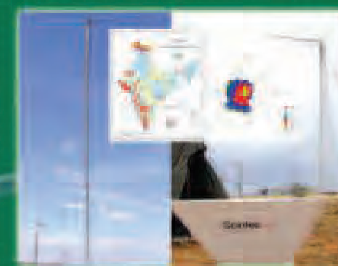
In this issue...

IWTMA
INDIAN WIND TURBINE MANUFACTURERS ASSOCIATION

Expertise and Research & Development for Wind and Solar Energy Stakeholders

Resource Assessment



Wind Energy

- Carry out Nationwide Wind Resource Assessment
- Estimation of Wind Potential in the country through Wind Atlas preparation
- Design and implement the comprehensive Resource Assessment Programme
- Analysis of wind data to identify Wind Farmable locations
- Verification and vetting of wind data generated by private entrepreneurs
- Consultancy services for Feasibility Studies, Technical Due Diligence, Micro-siting and preparing DPR for Wind Farming and Repowering assessment

Offshore Wind Energy

- Nodal Agency for Offshore Wind Energy development in India
- Met-Ocean Measurement.
- Demarcation of Offshore Wind Energy Blocks
- Geophysical and Geotechnical Studies

Solar Energy

- Solar Radiation Resource Assessment
- Investor & bankable grade Solar / Meteorological data
- GIS enabled Indian Solar Atlas
- Calibration of solar sensors as per International Standards
- Consultancy on Solar Energy Projects

Forecasting

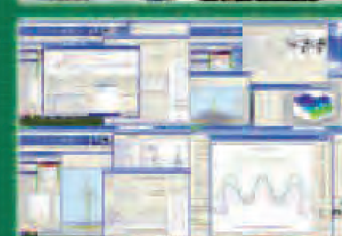
- Wind Power Forecasting Services
- Solar Power Forecasting Services

Testing (Large & Small)

- Power Performance measurements
- Load measurements
- Power Quality measurements
- Safety and function tests
- Yaw efficiency test
- User defined measurements
- Duration Test

The services are as per internationally accepted procedures & stipulations and certified as per the requirements of ISO 9001 & NABL accredited as per the requirements of ISO/ IEC 17025 : 2005

Standards & Certification



- Preparation of Indian standards on wind turbines
- Accord Type Certification to Wind Turbines. Type Certification Services are certified as per ISO 9001
- Issue the recommendation for grid synchronization to facilitate installation of prototype wind turbines
- Technical Due Diligence for Wind Farm Projects

Training

National, International and Customized Training on:

- Wind and Solar Resource Measurement & Analysis
- Wind and Solar Energy Technology
- Testing and Certification of Wind Turbines
- Installation, Commissioning and Operation & Maintenance of Wind Turbines
- Grid Integration of Renewable Energy System
- Forecasting of Wind and Solar Energy Production
- Seminar / Workshops on Wind and Solar Energy

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IWTMA
INDIAN WIND TURBINE MANUFACTURERS ASSOCIATION

Indian Wind Power

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Contents

Indian Wind Turbine Manufacturers Association

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IWTMA
INDIAN WIND TURBINE MANUFACTURERS ASSOCIATION

From the Desk of the Chairman – IWTMA

Dear Readers,

Greetings from IWTMA!

As we close the year 2020, economies and lives of various countries have suffered the devastating impact of the unprecedented COVID 19 pandemic. We salute the frontline Covid warriors who have demonstrated their untiring efforts to save human lives like our soldiers who are guarding our nation in difficult terrains. It is a matter of pride that our own indigenously developed COVID 19 Vaccine has been rolled out and we pray for normalcy to return, and a speedy revival of the economy.

The laudable target of the Government of India is to achieve 450 GW of renewable energy by 2030 of which wind alone is 140 GW. The pandemic had its worst effect on projects execution with installations of only ~880 MW between April to December 2020. We may end up with ~1300 MW by the end of March 2021. The one silver lining in this difficult period has been the inauguration of the largest Renewable Energy Park of 30 GW in the Kavada region of Gujarat. This park will be a combination of Wind, Solar and Wind Solar Hybrid under the leadership and vision of our Hon'ble Prime Minister. The Karnataka government has approved ₹42.40 billion for two wind-solar hybrid projects. The Maharashtra State Cabinet has issued its 'Unconventional Energy Generation Policy' to promote non-conventional source-based energy generation. The state aims to implement 17,360 MW of transmission system-connected renewable power projects by 2025. This includes 2,500 MW of wind energy projects.

The industry is confident that many other windy states will follow suit which will result in an all-inclusive PAN India growth. There is more good news with the Government of India proposing RE Parks which will facilitate private developers to work with the State Governments. The industry is pleased to note that a successful developer will get financial assistance from the Government both for DPR preparation and creation of infrastructure. Once this model becomes successful, project execution within timelines and without cost over-runs will be achieved to meet Government Targets. The current procurement model through competitive bidding rightly addresses transparent tariff determination. However, stakeholders must ensure that the projects are sustainable and profitable.

The vision of the Government is for higher penetration of RE and reduction in conventional power, which is in the right direction of creating a sustainable energy roadmap for the country. It is estimated that post pandemic the demand for power will increase by 12% in the medium period and RE can play a large role in the overall power portfolio. It is further seen that in the current financial modeling of procurement, a host of investors like the public sector undertakings, captive users, small and retail investors have been left out. We are informed that the Government is taking necessary enabling steps on open access for captive use and utilization of under-utilized STU transmission lines for CTU connectivity. This will greatly help speedier implementation of projects which are limited by inadequate transmission facility.

Power is considered as an essential commodity for daily use by various stakeholders. Further, power generation by wind has a different connotation. Wind power is benign and green, is commitment to 'AatmaNirbhar Bharat' by localization of up to 80%, supports thousands of MSME suppliers for components and has a positive impact on rural economy and employability of rural labour.

The budget gave boost to renewable energy by capitalisation of Indian Renewable Energy Development Agency (₹1,500 Crs.) and Solar Energy Corporation of India (₹1,000 Crs). Also, there was push for localization and AatmaNirbhar Bharat through increased duties on certain component imports.

RE sources such as Wind, Solar, Biomass and Hydro are seen in different silos and each has merits of its own. It is worthwhile to examine and implement dynamic bundling of power with a meaningful competitive tariff for acceptance by DISCOMs and benefit to the final consumers.

I would like to end on a positive note highlighting that Renewable Energy is one of the rare sectors in the world which has shown growth in 2020 despite the pandemic. The future is clearly bright for the RE sector and as demonstrated by China by commissioning of 45GW of Wind Energy in 2020, "where there is a will, there is a way."

The coming decade belongs to us, to renewable energy and the time to make an impact is now.

With regards,

Tulsi Tanti

Chairman

Danish Research Shows Almost No Birds Die in Collisions with Wind Turbines

> "The results confirm that birds are astonishingly good at flying around or over the turbines…almost no birds die in collisions, …it means that the erection of wind turbines doesn't need to be in direct conflict with natural areas…"

The results of a multi-year scientific study in Denmark has concluded that birds are quite good at avoiding wind turbine blades, putting a serious dent in a common argument raised by anti-wind and renewable activists. The new study, carried out by three relevant consultancies for Swedish power company Vattenfall, investigated the area around 11 turbines every three days for three periods of just over a month in both the first and third years after the erection of the 67.2MW Klim Wind Farm in northern Jutland, Denmark.

The research was carried out between August 2016 and May 2017 in the first year of operation, and August 2018 and May 2019 in the third year of operation. In an effort to determine an annual collision rate for the pink-footed geese and cranes, 11 selected turbines were inspected during autumn, winter and spring.

The Klim Wind Farm is a valuable scientific opportunity, located in the immediate vicinity of the international Natura 2000 bird protection area Vejlerne, where each day, thousands of birds leave their roosting areas in Vejlerne to fly out to nearby fields to find food. Unsurprisingly, given its location, many of these birds fly past the Klim Wind Farm.

According to the study – the results of which will be published in DOF BirdLife Denmark's scientific journal together with a 'peer review' for professional consolidation – in the first year of investigation, a total of 17 dead birds were found under the 11 selected wind turbines. In the third year, 22 dead birds or their remains were found. Importantly, the discovered dead birds or remains were not always those of the pink-footed geese, and no dead cranes were found which had crashed into the turbines.

According to the final analysis, the researchers determined that the evasive response for both the pink-footed geese and the cranes over the two study years worked out to be 99.9% – based on a population of 20,000-30,000 geese and several hundred cranes.

Moreover, the report concluded that neither pink-footed geese nor cranes were found where it could be stated with absolute certainty that they had died as a result of a collision with the wind turbines. However, for the sake of prudence, the authors of the report assumed that all birds or remains of birds found under the turbines were a direct result of turbine collision.

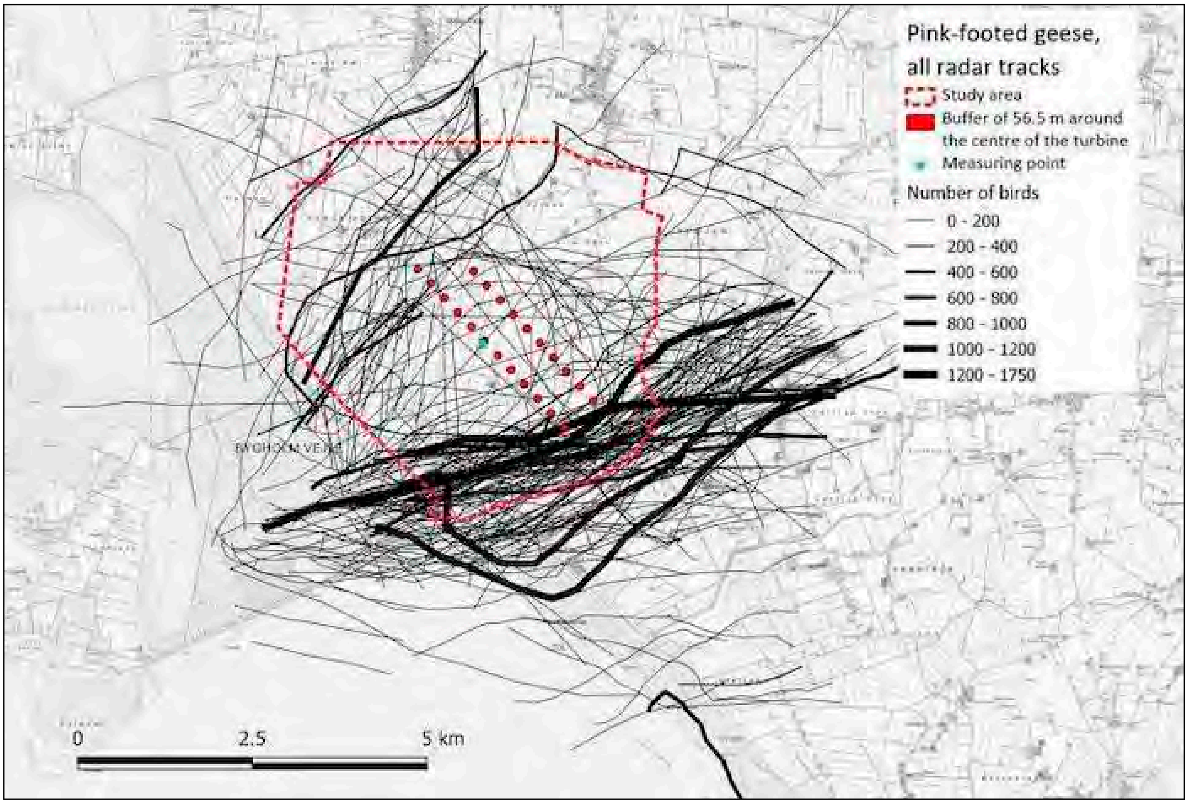
The area is an important natural area and quite extraordinary, as 20-30,000 pink-footed geese and several hundred cranes roost here," said Jesper Kyed Larsen, Bioscience Lead at Vattenfall Environment & Sustainability.

"Thousands of birds fly past the wind farm in both the morning and the evening during the winter period, which is why it's so positive to learn that the birds fly around or over the turbines to such a great extent. Hardly any of them hit the turbines, and the figure is considerably lower than previously believed.

"The results confirm that birds are astonishingly good at flying around or over the turbines. This is positive, not only because almost no birds die in collisions, but also because it means that the erection of wind turbines doesn't need to be in direct conflict with natural areas. This new knowledge should be taken into consideration in connection with the planning of new wind farms."

The report was carried out and authored by three recognised consultancies, including local professional ornithologists. The three authors were Jan Drachmann of the Pennen & Sværdet consultancy, who has a Ph.D. in population biology (evolution, ecology and genetics) from Aarhus University; Simon Waagner of Profus Naturrådgivning (PROFUS Nature Advice), a candidatus scientiarum cand.scient graduate from Aarhus University; and Henrik Haaning Nielsen of Avifauna Consult, a professional ornithologist with lengthy resume of work.

Sponsored by Vattenfall, which naturally has a vested interest in the outcome of the report's findings, the study was



Trajectory of pink-footed geese registered using radar with variations in width according to flock size. The red markings comprise the turbines and the study area.

carried out partly to prove that the Klim Wind Farm complied with its environmental permit – which stipulates that collisions must not exceed 75% of the current sustainable mortality rates for populations of pink-footed geese and crane.

However, importantly, the findings stand for themselves, as do the credits of the three independent authors who carried out the investigation.

Courtesy: Joshua S Hill, Renew Economy, 23 October 2020

Snippets

Solar Tariffs Continue To Reach New Record Lows with A Tariff Of Rs 1.99 Per Unit

Solar tariffs continue to reach new record lows with 19th December 2020 auction fetching a tariff of Rs 1.99 per unit. In the 500MW auction conducted by Gujarat's distribution company, NTPC, Torrent Power, Aljomaih Energy and Water Company, and Aditya Birla Renewables won 200MW, 100MW, 80MW and 120MW respectively at a tariff of Rs 1.99 per unit, sources said.

The lowest so far had been Rs 2.00 per unit which was reached in an auction conducted by Solar Energy Corporation of India, in November 2020. In the most recent solar auction conducted by Gujarat in August, the lowest winning tariff emerged at Rs 2.78 per unit.

Source: ET Bureau, December 20, 2020

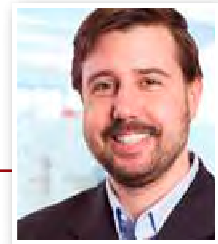
Nepal to Kick-start Overseas Participation on Indian Power Exchanges

Indian Energy Exchange (IEX) proposes to host buyers and sellers from countries such as Nepal, Bhutan and Bangladesh to participate in power trading with both buy and sell calls initially. As per the plan, power producers from neighbouring Nepal would be the first to get access to Indian power exchanges through a power trader to undertake both short-term and long-term power sale contracts.

Source: IANS, December 21, 2020


Leading Wind Energy in India Since 1995
With 23 years of leadership in the Indian wind market, Suzlon has been the largest contributor having built ~35% of India's wind installations. With over 12 GW of wind assets under service, Suzlon is the largest private player in the operations and maintenance services for energy assets.
With end-to-end business solutions Suzlon has led the green energy revolution to power India's social, economic and ecological development sustainably.
SUZLON
POWERING A GREENER TOMORROW
More than 18 GW of installations | Footprint across 18 countries | Largest product portfolio | R&D across Netherlands, India, Germany and Denmark
Leading global renewable energy player offering end-to-end solutions. To know more visit us at: www.suzlon.com | Join us on

Influence of Varying Temperature and Pressure on Calibration of Anemometer



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Introduction

In the recent industry scenario, we have moved towards reverse bidding process from Feed-in-Tariff (FiT) based Power Purchase Agreements (PPAs), which is quite challenging for the Independent Power Producers (IPPs) in terms of achieving good Internal Rate of Returns, for the turbine manufacturers to match with their competitors in terms of pricing as well as the lenders to mitigate risk in lending.

It is obvious that the Annual Energy Production (AEP) figures taken into the financial viability model plays a vital role, which depends on various factors and uncertainties. The most contributing and crucial parameter that directly influences the AEP at gross level is the wind speed measured and taken into consideration and the measurement setup indirectly influences the AEP estimations at different probability levels from 50% to 99%. Calibration of the anemometers used in the measurements, increases the confidence and reliability of the AEP estimation.

Anemometer calibration is crucial and helps to determine the quality of measurement campaign. Generally, it takes place in the wind tunnel with the constant, prevailing air temperature and atmospheric pressure conditions as recommended in IEC 61400-12-1 standard[1]. However, the performance of the anemometer's behavior can highly depend on site specific environmental conditions and hence it is recommended to select the appropriate anemometer for the particular measurement campaign. Furthermore, it is important to have a measure of the environmental influence on the wind sensor and thereby on the site assessment and the wind turbine control.

In the latest IEC 61400-12-1 standard[1], there are different influence parameters which have to be investigated during the anemometer classification. The air density is a function of air temperature and air pressure. To investigate the influence of a variation in air density, either the air temperature or the pressure can be altered. It is difficult to distinguish between the influence of changing air temperature and density if temperature variation is used to adjust the air density during the calibration. If both parameters, air temperature and air pressure, can be varied independently, the clear results will be obtained.

In standard wind tunnels air temperature and pressure can usually not be set deliberately. Therefore, the impact of these environmental conditions cannot be estimated reliably. A special, closed-return research wind tunnel has been developed by Deutsche WindGuard with the ability to vary the wind tunnel local pressure and temperature independently. The measurement results presented in this article are part of the report "VT180259_01_Rev0, Anemometer calibration at different air temperatures and air pressures."[2]

Technical Description of the Variable Air Density Wind Tunnel

The variable air density wind tunnel has a closed-return design, a closed test section and delivers a homogeneous flow with low turbulence (<0.5 %). It is designed for investigation of anemometers at different ambient pressures and temperatures. The design criteria were laid out in line with the requirements of IEC 61400-12-11. Based on the design criteria, the novel wind tunnel with a contraction ratio of 3.3:1, a 0.8 m long test-section, and a cross-sectional area of 0.5 m x 0.5 m was chosen and implemented at our headquarters as shown in figure 1 and 2. This provides an acceptable blockage ratio for the intended anemometer testing at different air densities.

In order to achieve a high-quality flow, there is a settling chamber before the nozzle that consists of honeycombs and screens to improve the flow quality and reduce the turbulence level. The wind tunnel is constructed with hermetically sealed sheet metal which ensures the reliable variation of internal pressure. Furthermore, the whole wind tunnel is placed in an insulated and temperature-controlled chamber.

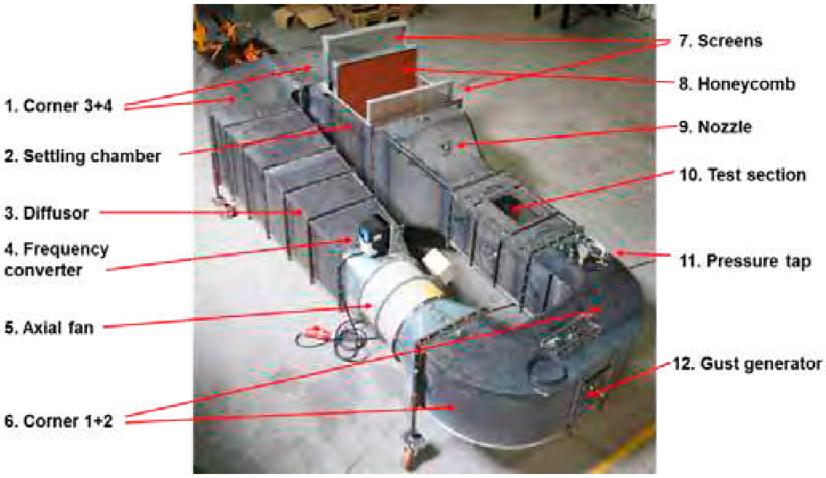


Figure 1:
Photo of the Variable Air Density Wind Tunnel during the Installation

Figure 2:
Photo of the Variable Air Density Wind Tunnel of Windguard Wind Tunnel Services

(Source: VT180259_01_Rev02)

Based on our experience in designing and building wind tunnels, well proven values of diffuser angles, contraction ratios, components and known pressure drop coefficients were utilized in the design calculations. An appropriately sized fan unit was chosen to compensate the calculated pressure loss in the wind tunnel system and produce the desired wind speed at the test section.

Calibration Procedure

To reduce the measurement uncertainties, first the anemometer has to be calibrated at normal ambient conditions in one of WindGuard's four accredited wind tunnels. Subsequently a measurement in the variable air density wind tunnel is performed at similar conditions (temperature and pressure) prevailing during the first measurement. From the measurements the transfer factor of the anemometer is determined.

For the measurements described in this paper, the following calibration procedure is used. While calibrating the anemometer in the variable air density wind tunnel, 4 m/s to 15.5 m/s wind speed range is considered.

In order to decrease type 'A' uncertainty, the minimum duration of the sampling interval 30s is considered. For each calibration run a linear regression analysis is performed, resulting in a calibration function with slope and offset for one particular air temperature and pressure respectively.

Calibration Procedure for Varying Air Temperatures

The air pressure is kept constant and the air temperature is decreased down to -20°C and increased by 5°C untill the maximum of 40°C. At each temperature step the calibration is performed.

Calibration Procedure for Varying Air Pressures

During the calibrations at varying air pressures the air temperature is kept constant at 10°C and the air pressure is increased by 50 hPa from 700 hPa up to 1100 hPa. At each pressure step the calibration is done.

Sample Results

Two similar cup anemometers with a frequency output from two different manufacturers were tested and both anemometers were equipped with roller bearings. In order to compare the performance, the ratio (k) of measured wind speed (if the anemometer is not calibrated for different air temperature and air pressure) and the reference wind speed is taken into account and expressed as:

$$k_{(T,p)} = \frac{f_{(T,p)} / v_{(T,p)}}{f_{(20°C,1000\ hPa)} / v_{(20°C,1000\ hPa)}}$$

where:

$f_{(T,p)}$: Frequency output at wind speed $v_{(T,p)}$ for a certain air temperature T and pressure p.

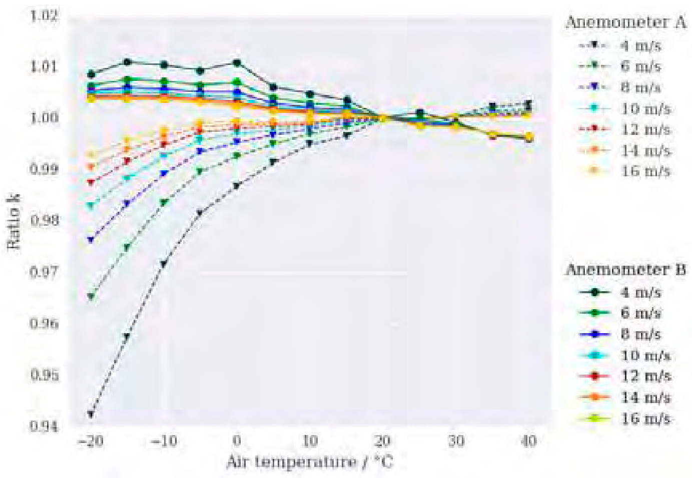
$f_{(20°C,1000\ hPa)}$: Frequency output at wind speed $v_{(20°C,1000\ hPa)}$ for measurements at 20°C air temperature and 1000 hPa air pressure.

Calibration Results for Varying Air Temperatures

The ratio k for the anemometers A & B calculated and normalized to the results at 20°C is illustrated in figure 3 for varying temperatures. Anemometer A has a decreasing ratio for decreasing temperatures whereas anemometer B has the opposite characteristic. Furthermore, the influence of varying the air temperature is stronger at lower wind speeds.

Calibration Results for Varying Air Pressures/Air Densities

The influence of varying air pressures/air densities is illustrated in the figure 4. The different air densities are obtained by varying the air pressure at a constant air temperature of 10°C. The ratio



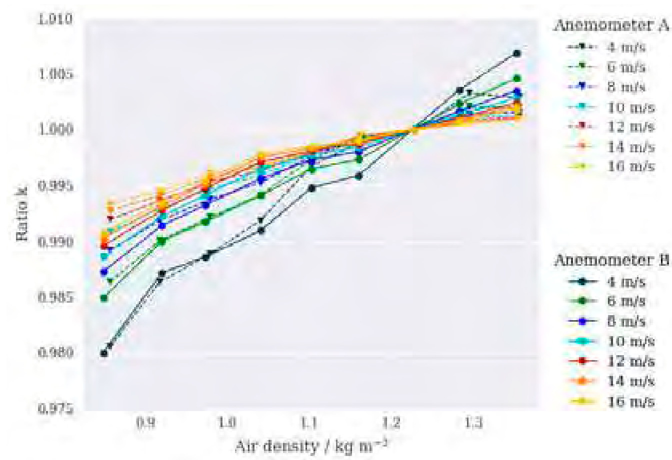


Figure 3:
Ratio k for Anemometer A and B at Varying Air Temperatures and Wind Speeds and at Constant Air Pressure
(Source: VT180259_01_Rev0[2])

Figure 4:
Ratio k for Anemometer A and B at Varying Air Density and Wind Speeds and at Constant Air Temperature
(Source: VT180259_01_Rev02)

k for the anemometers A & B is calculated and normalized to the results at 1000 hPa and corresponding to an air density of approximately 1.23 kg/m³. The influence of varying densities for both anemometers is similar. Both anemometers have a decreasing ratio for decreasing pressure. The influence is again stronger for lower wind speeds.

Conclusion

The above results show the influences on the anemometer's performance at varying environmental conditions, especially at low temperatures. The opposing characteristics of both anemometer types demonstrate that a change in air temperature can have other effects than just an increase in bearing friction. Therefore, it is necessary to perform tests in which the whole anemometer is exposed to different temperatures.

Moreover, as the air density is dependent on air temperature and air pressure, the influence of the air density and air temperature on cup anemometer measurements can be very different. None of these aspects are covered in IEC 61400-12-11.

If cup anemometers are used in cold climate regions or in higher altitudes, a standard calibration can lead to an under or over estimation of the wind speed. The magnitude may be in the order of several percent in wind speed, which is an even greater deviation in wind power. Also, the use of anemometers for the wind turbine control in these regions may result in a delayed start of power production, especially as the influence of air pressure and temperature is the highest for low wind speeds.

The correction algorithm may be developed considering air pressure, air temperature and wind speed. This correction function has to be individually developed for each anemometer type. Recent developments in the industry have unveiled anemometers that have facilities to be programmed with correction algorithms.

References

1. IEC 61400-12-1, Edition 2.0, Wind energy generation systems – Part 12-1: Power performance measurements of electricity producing wind turbines, IEC TC/SC 88, 2017
2. VT180259_01_Rev0, Anemometer calibration at different air temperatures and air pressures". Busche Peter et al. 2018. https://www.windkanalzentrum.de/veroeffentlichungen.html?file=files/cto_layout/img/unternehmen/Ver%C3%B6ffentlichungen/Anemometer%20calibration%20at%20different%20air%20temperatures%20and%20air%20pressures_2018.pdf

Snippet

ReNew Power, Greenko Keen to Buy out Chandigarh Discom

Two of India's largest green energy firms, ReNew Power Ventures Pvt. Ltd and Greenko Energy Holdings, are among 10 companies that have shown an interest in buying out Chandigarh's electricity distribution company (discom). Their interest in the discom business comes against the backdrop of their strategy to capture value across the electricity business chain. The others who have bought the request for proposals (RFP) document made available from 10 November for the Chandigarh discom are Tata Power, CESC Ltd, Torrent Power, Adani Group, NTPC Ltd, GMR Group, India Power Corporation Ltd, and Sterlite Power. These firms have been attracted by the robust per capita power consumption of these discoms. The Chandigarh discom sale also marks the start of India's efforts to privatise the electricity discoms of its Union territories as part of its next generation power sector reforms.

(Source: Mint, 24 Nov 2020)

RECENT TECHNOLOGICAL DEVELOPMENTS IN WIND TURBINES

Software Upgrades, Aerodynamic Modifications and Controller Optimization

Deepika Shenoy
Project Development Engineer
DNV GL – Energy

Wind and solar tariffs in India have fallen significantly in the last few years, where solar tariffs reached a new low of INR 2 per unit recently due to the reverse auction model. This new price will have tremendous pressure on the wind industry to further bring down its levelized cost of energy (LCOE). Some of the major trends developing in this direction are the rise of bigger turbines, software and hardware upgrades and controller optimization for site-specific conditions.

The Rise of Bigger Turbines

Besides lowering LCOE, the wind industry has also the challenge to harness wind power from sites with relatively lower wind velocity, as sites with higher wind velocity are already developed. The current industry approach to tackle both challenges is to come up with a design with longer rotor diameter and higher hub height. While longer rotor diameters enable to capture more wind, the higher hub height allows to access higher wind velocity.

In India, as per the recent Revised List of Models and Manufacturers (RLMM) list, turbine models with more than 130m rotor diameter, the hub height of up to 140m and capacity of more than 3 MW are available for onshore wind. For offshore wind, these parameters are even much bigger – We have even recently undertook the conceptual design of a wind turbine model of 20 MW.

The turbine design process consists mainly of determining hub height, rotor diameter and corresponding changes in the major components. It is an iterative process to select suitable materials and optimise the design parameters for the lowest LCOE. The design process is run against multiple options to bring down the cost while ensuring maximum power output at every wind speed bin level while addressing specific meteorological conditions. The design process is different now than compared to 10 years ago in terms of iterations and granularity of the optimisation level. In DNV GL, a tool that we use to help our customers in the turbine design process is 'Turbine.Architect.' The tool supports turbine design and component technology development by quantification of the technical impact of design and component technology on both the turbine generator as well as the entire wind farm, from the foundation to the electrical infrastructure.

The tool builds a detailed virtual model of the turbine, with realistic load envelopes and strength margins, down to the level of tower plate thickness and sizing bolted ring flanges. With such detailed modelling, issues such as transportation geometry constraints and frequency of vibration interactions can be addressed accordingly. It considers the complete picture, by bringing together cost modelling of not just the machines but the balance of plant, operations and maintenance and economic aspects such as a discounted cash flow model where estimated costs and yield are escalated to LCOE and Net Present Value (NPV). All these factors allow for decisions to be made in the most comprehensive way.

Limitations to Bigger Turbines

It is expected that hub heights and rotor diameters would continue to increase, and wind turbine designs would continue to be optimized for the low wind site conditions. However, the bigger question is how far is this trend able to continue?

With higher hub heights and longer rotor diameters, wind turbines are able to harness higher wind speeds to generate more power; but the cost of wind projects also increase in the aspects of manufacturing, transportation and installation cost, including foundation costs. Once we have passed a certain point, the advantage of more wind and higher velocity may not be enough to compensate for the additional costs incurred. In fact, some of such wind turbine models are not techno-commercially suitable at sites where shear factors are relatively low.

Other than technical challenges, logistical issues from the transportation of wind turbines on Indian roads, and therefore installation, are also limiting the rise in wind turbine sizes. While there are innovations going on for navigating sharp road turns to accommodate the transportation of longer blades, this is still a challenge.

So, all in all, one can say that logistical challenges, as well as higher costs vis-à-vis gain in power output would put a limit to the increase in wind turbine sizes.

Software Upgrades

In recent years, we are seeing software updates by wind farm manufacturers to maximize power output to harness all possible wind bins from existing/installed wind turbines in given environmental conditions. Many manufacturers are now offering power booster and power performance optimization services, with options to operate turbines at wind velocities where cut-in speed is being lowered. Similarly, High Wind Ride Through (HWRT) is being implemented through a software upgrade where the operation of the wind turbine is extended beyond standard cut-out wind speed.

Aerodynamic Modifications

In addition to software upgrades, there have also been attempts to upgrade wind turbine hardware to improve efficiencies. Such performance upgrades mainly come from modifications where add-on of aerodynamic devices such as vortex generators, flaps, leading-edge repair, etc. improve wind turbine generation performance. Such add-ons increase lift, thereby increasing torque through delays in flow separation of wind, or increasing aerodynamic parameters for higher efficiencies at specific wind conditions.

Controller Optimization

Apart from the upgrades mentioned above, which can be applied to wind turbines that have been installed, we are also starting to see a rise in performance upgrades where modifications of controller settings allow turbines to operate at more than rated capacity under the specific condition that loads remain within limits that manufacturers have set. For example, through a modified controller setting, a 2.0 MW turbine can operate at 2.2MW, thereby increasing the power output by 10%. Other enhancements through control systems are for instance pitch optimization, improved soiling operations and uprating to improve performance.

At the wind farm level, some upgrades include wake optimization and better demand side management. These optimization techniques, applied alongside other modifications to individual wind turbines increase the overall production capacity of the wind farm.

Need for Reliability and Safety

While pressures to reduce LCOE of wind projects are leading to the optimization of wind turbine designs, it is also important that the structural integrity and safety of wind projects are not compromised. Earlier turbine models had enough design margin and therefore, many of them continue to operate even beyond their designed lifetime. However, given the current optimization practices, design margins have been significantly reduced and hence it is important that the whole value chain from manufacturing and installation to operation and maintenance are undertaken with highest standard and accuracy band. The wind industry has proven its reliability and safety through maintaining a very high standard for more than two decades, and it is in the very interest of the industry to maintain the same in future.

Snippets

Solar and Wind Power Costs in India will be Comparable to Coal in 2025: Moody's

Power generation from solar and wind projects will likely be cost-competitive relative to coal-based power in India in 2025-2030 period, according to Moody's Investors Service, the global provider of credit rating, research and risk analysis. "We expect the LCOE for new solar and onshore wind – both with battery storage – will be similar to the LCOE for new coal power in 2025, if the LCOE for the former declines at a CAGR of 8% – 16% from H1 2020 to 2025, and in 2030, if the LCOE range declines at a CAGR of 4% — 9% from H1 2020 to 2030," The firm said in a report. The numbers are broadly similar for India and China. It added that the LCOE for those renewable sources with the same storage battery capacity as generating assets declined at a CAGR of 23%-40% from H1 2018 to H1 2020 in China and India.

(Source: ET Energy World, November 19, 2020)

India Experienced First Decrease in Carbon Emissions in Four Decades

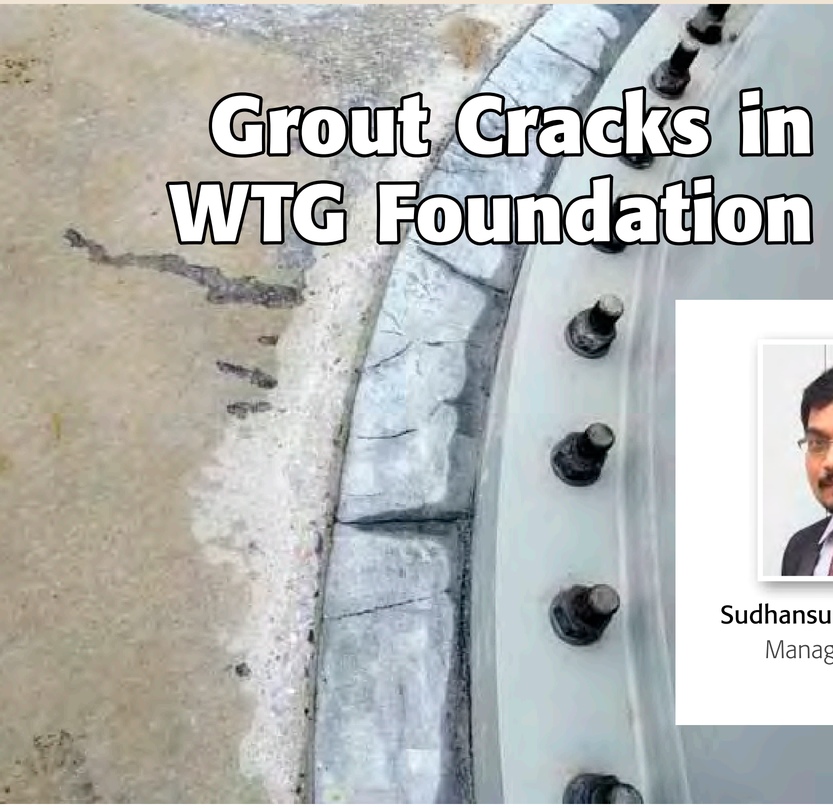
Lower energy consumption during the lockdown period related to COVID-19 and a decreased share of coal in the electricity mix has led to the first decrease in carbon dioxide ($CO2$) emissions in four decades in India. Though temporary, the country experienced a 15 per cent decrease in emissions in March and a 30 per cent decrease in April this year.

(Source: ET Energy World, November 17, 2020)

Blockchain Gets a Push in US Energy Standards Board

The North American Energy Standards Boards (NAESB) puts blockchain and cybersecurity at the front of digital technology standardisation drive. Other technologies and areas reviewed in the digital report include cloud computing, deployable shareware, 5G, energy usage data, data governance requirements, renewable energy certificate tracking, Internet of Things and data analytics.

(Source: Smart Energy, 8 December 2020)



Grout Cracks in WTG Foundation | How to tackle?

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Abstract

The study pertains to a proposal of manufacture of new grout material and a self-healing technology for the cracks developed in the grout based on the design experience and expertise on the grout subjected to fatigue loading for wind turbine foundation and based on the past failure analysis of these grout material. With bigger and larger turbines, the problem will further amplify and a remedial measure by producing an apt grout for the wind turbine generator should be taken to task so that the future of turbines is safeguarded. The investor of wind turbines should understand the sensitivity of this component as this might jeopardize the entire cash inlay strategy.

Introduction

Onshore wind turbines are enormously growing in renewable energy generation. As per IRENA 2019 report, there is an increase of 3.75 times of MW capacity over a decade (from 2009 to 2018) in global context, out of which India has increased to 3.23 times that of the MW existed in the year 2009 till 2018. As of 2019 report, onshore wind energy makes up 23% of the world's renewable energy capacity, and the same is 30% in India as per 2018 statistics, with no offshore energy installations in India (Renewable Energy Capacity Statistics 2019). Support structures for these onshore wind turbines are usually gravity-based or piled reinforced concrete foundations and these structures are considered as least importance for an onshore wind turbine regardless of being a critical structure. In renewable energy generation, almost 95% of wind turbine generator (WTG) failures are attributed to problems in gearbox, blades or generator, compared to failures of towers and foundations[1]. Being a quite niche sector that involves multiple domain knowledge is sometimes far reached, there seems to be a lot of facts which do not come out in the public domain at ease as many operating persons do not have domain expertise to tackle such problems with wind turbine foundations and the failures are generally hidden. The companies experiencing the grout cracks in WTG foundations should share their experience so that the studies and improvements can be made better in this regard. However, for continued investment and for maximization of environmental benefits, it is vital to extend the life of these support structures or to ensure their design life time at least.

Cracks in WTG foundations can happen either before hardening or after hardening of mortar. The cracks can be classified based on the structure of cracking, viz., physical (different types of shrinkages, accidental), chemical (corrosion, carbonation), constructional (movement of formwork), structural (design fault), thermal (seasonal temperature variation), etc. Among the types of cracks, cracks in foundation are the ones first initiated in the first 3 to 5 years of commissioning of a wind farm. This technical paper covers the importance of cracks in grouts which we have practically faced in the field and what should be the future research requirement to overcome this defective practice. The cracks in the grout can entirely jeopardize the load transfer mechanism causing undue stresses on the foundation concrete and the interface. The impact of grout cracks may not limit it residence within the grout but because of the crack openings in the grout its functionality is lost and the top concrete will receive the abnormal stresses which they are not designed for as the load transfer mechanism is further widened out surpassing the pedestal face.

Impact of Cracks in WTG Foundations

As per IRENA Renewable Energy Technologies: Cost Analysis Series, 2012 Report, the cost of the support tower with foundation is slightly more than one fourth of that of a WTG out of which, the contributing cost for foundation is around 5-6%, again a quarter of the cost of the tower. Further, the report suggests that for onshore wind power projects, foundation is one of the key areas where cost reduction can be implemented. While trying to reduce the cost, the quality and the life of the structure cannot be forfeited. We should adhere to the Codal guidelines as well as come out with an economical design. Although in terms of the percentage of cost is least for foundation, but strength of the foundation is very important for the overall reliability of WTG. While failures often get widely reported in media simply because of the high visibility of turbines, the percentage of structures that break is low compared to failures of turbine blades as reported by US based insurance company (2015).

Successful and safe installation of wind turbines largely depend on the materials which connect the tower to its foundation. In general, loads transferred to foundation are of axial load, bending, torsion, rotation, vibrations and combined effects of all these, besides interaction of the soil and foundation (Standard Design Report of NeXHS 2019). Grouts play a major role in transferring these loads from the tower structure to the foundation. Hence, a careful design and selection of the grouting material is of utmost important.

Construction Manual (SOP) as prepared by NeXHS (2019) has the following guidelines for grouting process:

1. Selection of suitable formwork material (GI sheet/MS plate). Figure 1 shows the typical formwork using MS plate at a site.
2. Calculation of minimum gap required both inside and outside
3. Height of formwork above the grouting level
4. Ensuring the uniformity of the gap all around
5. Sufficient support to formwork
6. Surface preparation for grouting by suitable methodology
7. Surface treatment before grouting
8. Selection of adhesive bonding agent between concrete surface and grouting surface

Figure 1:
Formwork for Grouting

Understanding the Cracks in Grout

Cementitious and epoxy-based grouts are generally used for WTG foundations. Recommended ways and means as documented in the project manual are not religiously followed while executing the construction and installation of projects and often result in deviations. Such field deviations lead to cracking in grouts in common as can be seen in Figure 2. Further, the types of cracks in grouts as experienced by us while executing and during the life of the project in the field are discussed in the following sections. The process of grouting at site is demonstrated in Figures 3 and 4.

Figure 2:
Radial Cracks on Tower Pedestal – Crack Expanded

Figure 3:
Process of grouting at site

Figure 4:
While and after grouting

Common Types of Cracks Observed in Grouts

The most common types of cracks observed in grouts based on visual inspection[2] are:

- Thin cracks including shrinkage and autogenous cracks
- Vertical cracks on the voids provided to allow access for grouting
- Horizontal cracks at the connection
- Thermal cracks while processing and due to improper curing especially in regions of water scarcity.
- Material cracks due to lack of strength or differential grouting material or metallic contents in the grout
- Corrosion cracks due to carbonation or at the connection
- Structural cracks due to poor design
- Cracks arising out of artisanship

Main Causes of Grout Cracks

To overcome these cracks, precautionary measures are necessary while and after the execution of project. Some of the main causes of grout cracks are listed below:

- Inappropriate selection of material
- Non-uniform grouting material
- Two different grouts for one pour in a site
- Insufficient injection of grout
- Lack of provision of expansion joints that don't permit breaks in between two successive pours
- More number of sharp corners or excess material at the edges as sharp corners tend to break and hence chamfered edges may be provided to limit stress-related cracking
- Weak grout as against equivalent strong grout
- Sequence of form release to avoid differential restraint on the grout during its cure
- Poor performance of workmanship
- Poor structural design

Research Requirement to Tackle Grout Cracks

Based on the pattern of failures from a survey on wind farms located in southern part of India by the authors, it is observed that in each wind farm, there are issues related to grout to the extent of 3% to 5% after commissioning. Figure 5 shows the location of wind farms considered for the selected study. Figure 6 shows the representative number of wind turbine foundations affected by the issues related to grout.

Figure 5:
Location of Wind Farms (■)

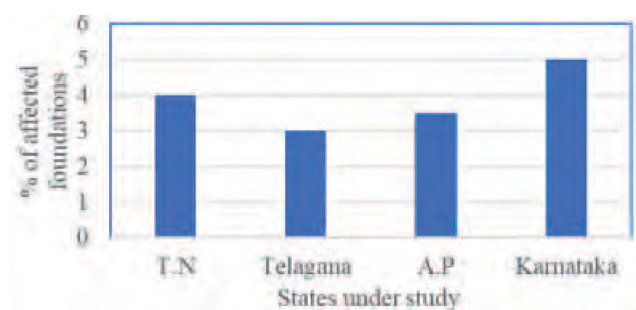

Figure 6:
Foundations Affected by Issues Related to Grout

Failure analysis

A preliminary research by us on cracks was initiated by considering the actual crack found practically in the field. By applying failure theory, propagation of cracks is further analyzed using Abaqus.

Mix Design of High Strength Grout

We have initiated a high strength grout, which would possess good mechanical and fatigue response, durability and long-term response to damages. Research is on-going at our R&D centre to possess a few superior properties for a high strength grout mix, such as:

- Should act as a transition material possessing extra high properties.


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- Has to be designed to have a very high fatigue resistance.
- Should be capable of transferring or absorbing dynamic loads in a predictable and consistent manner.
- Grouts should have vibration damping capability, as well as adequate compressive strengths.
- Has to be a non-shrink grout and preferred to be cement based and should have a stable volume to maintain the bearing capacity.

Self-healing technology

Research has been initiated on self-healing technology especially for the grout and concrete so that any crack development in the grout can be addressed through the self-healing compound.

Conclusion

Recent studies in Germany, where more than 20,000 wind energy systems are in place, have found that up to 30 percent are affected by foundation damage within the first three to five years[3]. Causes of this damage include the high number of load changes (up to 7 million load changes per year). The loads must be transmitted through the anchors and through the grout bed that serves as the link to the foundation[3].

According to American Wind Energy Association (AWEA), average hub height of utility-scale wind turbines installed in the U.S. jumped from 58 meters to 88 meters over a period from 2000 to 2018 and in global context it is aimed to build ultra-tall towers to the extent of 160 m height to boost the capacity factor (www.greentechmedia.com). However, while trying to expand the markets by reducing the tower costs perhaps by 15% to 20% by 2030 (IRENA 2019), use of lightweight materials, hybrid towers and other innovative technologies to achieve that height in-turn require a high strength grout to strengthen the foundation. Wind energy continues to grow, besides solar energy during this COVID-19 pandemic, even as global electricity demand has been declining in many regions (www.greentechmedia.com). A non-shrink cement-based high strength grout is the requirement at this moment of the time to tackle grout-based cracks. It is a challenge for the researchers in the field of renewable generation, which our R&D Centre has taken up. Preliminary mix design developed is a cement-based (OPC) non-shrinkable grout by using only high range water-reducing agent, aiming to achieve 150 MPa and further lab-scale mechanical tests are being continued.

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Snippets

Renewables meet 46.3% of Germany's 2020 power consumption, up 3.8 pts

Renewable sources met 46.3% of Germany's power consumption in 2020, 3.8 percentage points more than in 2019, utility industry association BDEW said, adding that parts of the increase came from a drop in usage in the coronavirus crisis. Germany wants to raise the share of renewable in its power mix to 65% by 2030 and is just finalising a green law reform bill this week to step up its efforts.

(Source: Reuters, December 14, 2020)

Cabinet Approves CERC Proposal to Exchange Information with FERC, US in Electricity Sector

The Union Cabinet has approved the Central Electricity Regulatory Commission's (CERC) proposal to enter into a Memorandum of Understanding (MoU) with the Federal Energy Regulatory Commission (FERC), USA to exchange information and experiences in the electricity sectors. As per a statement, the MoU will help improve the regulatory and policy framework to develop efficient wholesale power market and enhance grid reliability.

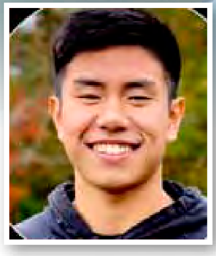
Source: ANI, December 17, 2020

Tamil Nadu Owes Most to Power Generation Companies

According to a study released by ICRA, the state utility Tangedco has huge outstanding payments of Rs 18,520 crore, to power generating companies. In contrast, Gujarat discom's outstanding was Rs 448 crore, Maharashtra's Rs 7,358 crore and Karnataka's Rs 7,127 crores as of October 2020.

(Source: TNN, December 24, 2020)

Technological Advancement in Wind Turbines



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Wind power technology has been an essential source of electrical energy for several decades now. Wind turbines convert the kinetic energy present in the wind in to electricity. The process occurs when wind forces the blades of a wind turbine to rotate, which is then connected to a gearbox increasing rotational speed to spin a generator to produce electrical energy. Wind turbines have evolved in many aspects to remain relevant in the modern world of renewable energy. Researchers in industry and academia are working diligently on developing highly efficient and reliable wind turbine technology that saves on energy costs. In efforts to improve the reliability of wind turbines, the challenges of maintenance and inspection need to be overcome to ensure that wind turbines will perform well consistently. Wind turbines are vulnerable to many natural hazards such as lightning, strong winds, strong waves and corrosion. These vulnerabilities could lead to significant damage which demonstrates why wind turbines require constant monitoring and maintenance. Industries are steering away from manual inspection of wind turbine blades with newly innovated autonomous robots and drones that can perform inspections without human intervention. Recent developments have also been made to improve the efficiency of wind turbines through the implementation of longer turbine blades, along with different shapes and configurations. The history of wind turbine development has illustrated that the growth in size of wind turbines over the years corresponds to greater energy production. In addition, researchers are improving the viability of offshore wind turbines, by implementing floating substructures to these wind turbines. Although efficiency and reliability are top priorities for wind turbine technology, the total cost is also important for considering the overall feasibility. These new developments aim to maximize performance while minimizing costs.

One of the most effective ways to reduce maintenance costs in wind turbines is to locate internal and external damages as early as possible, which will increase its service life. As damages worsen, the repair cost will increase as well, possibly requiring replacement of parts. Researchers are developing drones and robots that will perform inspections on wind turbines autonomously, which will increase maintenance efficiency and prevent drastic damages. Energy cost is also a vital consideration of wind turbines. By increasing the size of wind turbines, there is greater electricity production, decreasing energy costs associated with each turbine. Higher wind velocities are available at higher altitudes and a wider area of wind can be captured by bigger blades, emphasizing the importance of increasing turbine height and rotor size. Unfortunately, increasing wind turbine size comes with added complexity and greater material cost. Additionally, larger wind turbines require more materials to construct, which will cost more, especially in the case of offshore wind turbines. Many offshore wind turbines are grounded to the bottom of the water and extend above the water's surface, adding a tremendous amount of height to the wind turbine. However, researchers have developed a floating substructure for offshore wind turbines that will ease the installation process and reduce material cost compared to fixed-bottom substructures. There are notably higher and more consistent wind speeds offshore; indicating, offshore wind turbines have the potential to generate more electricity than onshore wind turbines. Therefore, this floating substructure development is worth the investment.

Autonomous Robotic Inspection

One of the biggest concerns of wind turbines is the actual service lifespan relative to the calculated lifespan. Currently, the actual service life is not reaching up to the expected service life. The maintenance required for the enormous structure of a wind turbine is no laughing matter. The blades of the wind turbine are subjected to unexpected disturbances such as lightning, hail, rain, humidity and other forces, but it is not possible to dismantle the wind turbine in order to perform maintenance. To combat this issue, aerial drones have been implemented to locate surface damages. Subsurface damages, on the other hand, are harder to pinpoint. Sandia National Laboratories is working alongside International Climbing Machines and Dolphitech to construct a robot that would be able to attach itself vertically to the surface of the wind turbines, utilize onboard cameras to examine potential surface damages, and phased-array ultrasonic imaging to uncover internal damages. According to Dennis Roach, Sandia senior scientist, "phased-array ultrasonic inspection can detect damage at any layer inside the thick, composite blades." Wind power plants are also moving towards autonomous drone inspections to monitor the status of wind turbines on a daily basis. After the visual inspections, a "robotic crawler" would be deployed to areas with potential damage to do a thorough inspection. Further developments include automated robotic crawlers as opposed to having an operator manually deploy it. The goal is to locate any damages as soon as possible to minimize the cost of repair and blade replacements as well as lower wind turbine downtime leading to cheaper costs for wind energy and longer service life. Manual inspections using a camera and telephoto lens used to be the main method for identifying damages and due to human limitations, damages are usually too critical by the time they have been detected. Autonomous inspection is more suitable given the size and location of the blades, showing high potential for onshore wind turbines, but even more so, for offshore wind turbines given their remote location.

Sandia National Labs is working to equip the drones with infrared cameras to detect damages through thermal imaging. The method involves heating the blades of the wind turbines under the sun and then placing the blades under the shade. Without the sun, the surface of the blades would cool down as the heat diffuses from the surface into the internal material. However, damaged areas, such as cracks, prevent the heat from diffusing inwards, which leaves the surface of the damaged area hot. These hot spots that show up on the infrared cameras indicate damage. The infrared cameras, in combination with a lidar, achieve a high-resolution image that helps locate the damaged area on the blade.

Figure 1:
Robotic Crawler in action

Maintenance costs constitute a large portion of the total costs of a wind turbine. These robots and drones will work to reduce maintenance costs and improve the sustainability of these large infrastructures. Another considerable share of the total costs is that of materials required to build these large structures, especially in offshore wind turbines that must extend to the bottom of the ocean to stay grounded. Recent developments have aimed at reducing material costs and improving the viability of offshore wind turbines through the implementation of floating substructures.

Floating Substructure in Offshore Wind Turbines

Wind farms are generally found onshore or offshore. Offshore wind farms can produce a bountiful amount of electrical energy given the strong wind velocities at sea, but economic difficulties are met with offshore substructure and installation. The capital expense of producing offshore wind farms exceeds that of onshore wind farms due to the challenges met underwater. Approximately 35% of the capital expenditure for offshore wind turbines is used to pay for substructure and installation expenses. Given the depth of ocean water, more materials are used, driving costs higher for offshore wind farms.

The National Renewable Energy Laboratory (NREL) has come out with an innovative project to combat the high cost of offshore wind turbine installation, called SpiderFLOAT. SpiderFLOAT technology utilizes floating substructure designs, which aims to reduce wind energy costs. The floating substructure allows for less demanding construction of offshore wind turbines on the installation site. The material requirements would be reduced as compared to fixed-bottom substructures. The SpiderFLOAT ensures easier maintenance due to fewer transportation constraints and on-site manufacturing for installation purposes. The SpiderFLOAT also targets the reduction of steel composition in the substructure. A simplified representation of the SpiderFLOAT is shown in Figure 2.

With new advances in floating substructure technology, offshore wind farms are becoming more economically viable. Another way to improve the economic viability of wind turbines is by maximizing power generation which will minimize energy costs. Throughout the development of wind turbines, a noticeable

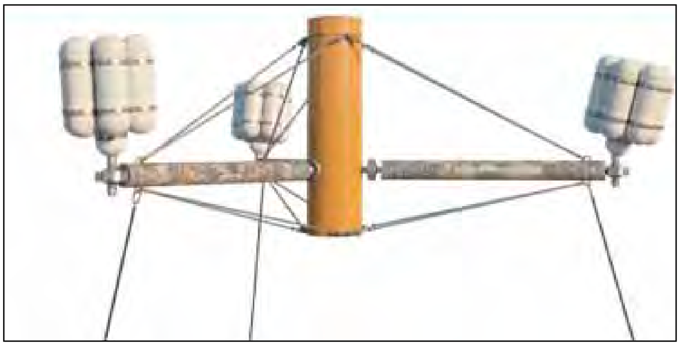

Figure 2:
Simplified Model of the SpiderFLOAT Design

trend is the increase in turbine size. While the growth of wind turbines is ideal, challenges are encountered in the process.

Challenges to Increasing Rotor Size

In an attempt to reduce energy costs and maximize energy production, researchers are looking to increase the size of the rotors. Currently, the National Renewable Energy Laboratory and Sandia National Laboratories are working together for DOE's Big Adaptive Rotor (BAR) project. The aim is to design 5 MW land-based turbines with 206 m rotors.

The idea behind larger and longer turbine blades is the increase in aerodynamic efficiency. With bigger blades, more wind is captured which contributes to a higher torque. As a result, more mechanical power is produced that gets passed through the shafts to the generator, producing a greater amount of electrical power. However, transportation and manufacturing difficulties are faced when scaling the blades at a size that is more cost-efficient for energy as bigger blades also require more materials increasing cost.

NREL and Sandia are looking at a downwind rotor configuration such that the rotor is facing the downwind side of the tower. Conventional wind turbines are typically positioned in an upwind direction. The blades of these upwind wind turbines generally have a high stiffness requirement, so that the blades do not touch the tower of the wind turbine. Higher stiffness demands are coupled with heavier blade mass. By positioning the wind turbine in a downwind configuration, the stiffness requirement is lessened because the wind would be pushing the blades in the direction away from the tower. This ensures greater tower clearance as the blades are not likely to interfere with the tower, and lighter blades are possible. Variable coning is incorporated into downwind systems to allow for passive control of the turbine's performance as the rotor tracks the direction of the wind using the cone mechanism. Figure 3 shows a comparison between two different wind turbine configurations. Knight and Carver's Wind Blade Division and Sandia National Laboratories are developing a wind turbine blade that could potentially capture 12% more energy, which has been named the Sweep Twist Adaptive Rotor (STAR) blade. The blade has "a gently curved tip, which, unlike the vast majority of blades in use, is specially designed to take maximum advantage of all wind speeds, including slower speeds."

Figure 3:
Rotor Configuration
Traditional (left) vs Downwind Coned (right)

Researchers are considering changing the shape of the blades as well to allow lighter blades. This approach combats aeroelastic instability but faces difficulties in "controls, manufacturing and reliability." Designers are aiming at multi-element airfoils that would improve aerodynamic efficiency by "optimizing the placement of the spar caps without increasing the overall thickness of the airfoil". This would minimize blade mass and loading impacts while maintaining strong structural integrity. To overcome the transportation concerns of larger and longer blades, wind turbine blades are being manufactured in modules. Therefore, these segmented blades can be shipped out separately and assembled on-site. Further weight reducing considerations are being made on the segmentation of the inner structure of the blade.

Direct Drive Generators

Another contribution to the overall maintenance and material cost of wind turbines is found in the drivetrains of the wind turbines. The drivetrain of the wind turbine facilitates the conversion of mechanical power into electrical power. Generally, the rotor is connected to a low-speed shaft and the low-speed shaft is connected to a gearbox. The gearbox amplifies the rotation of the low-speed shaft to speeds high enough to generate electricity through a high-speed induction generator. The downside is the high maintenance required for functional gearbox operation due to the abundance of moving constituents in the drivetrain. The drivetrain experiences additional loads and stress caused by the large movements and forces exerted from the torque of the rotor. As a result, the gearbox must be adjusted to compensate for those disturbances.

Wind turbines can also consist of direct drive generators that require fewer moving parts due to its ability to generate electricity at the speed of the rotor. Hence, the gearbox is not required for direct drive generators. However, direct drive generators typically require permanent magnets which allow the generator to reach the necessary output frequency. Permanent magnets promote high efficiency but consist of rare and expensive materials. These materials are also heavy, negatively contributing to the weight of the generator. Heavier generators require stronger support from the tower which is more costly; subsequently, offshore floating substructures would have to increase in size to support heavier wind turbines. Therefore, minimizing the weight of the generators while improving its performance is a high priority. The DOE is planning to develop lightweight direct drive technologies that utilize superconducting generators, eliminating the need for rare materials.

New prospects are being explored for high performance and lightweight wind turbines that will minimize capital expenditures for the production of energy. The size, shapes and configurations are being changed as the years go by and offshore wind farms are becoming more viable through the implementation of floating substructures. Ultimately, wind turbines have been a renewable

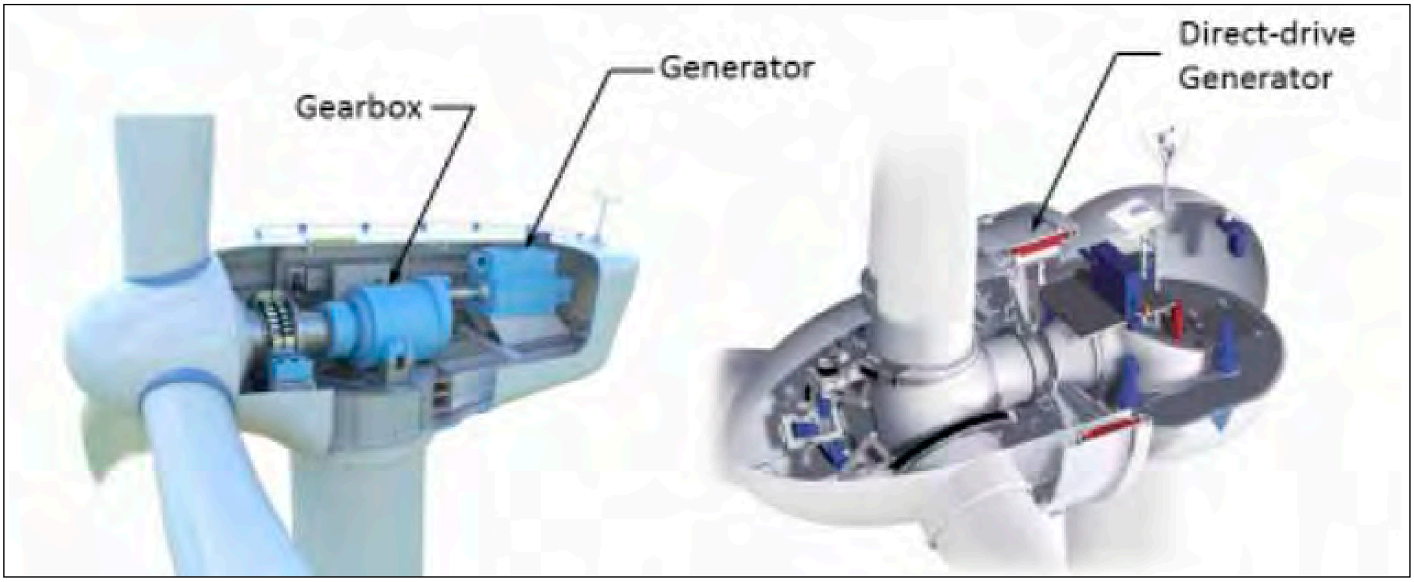

Figure 4:
Comparison between Geared Generator and Direct-Drive Generator

and non-polluting source of energy for many decades and it is only going to improve from here.

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Higher Reliability and Longer Lifetime with a Silicon-based Additive Technology

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Wind turbine maintenance and component failure is costly, with bearings and gearboxes contributing significantly to downtime and cost of repairs. Here we present our technology, REWITEC, a microparticle-based lubricant additive that has been proven to repair existing damage and protect the system for the future improving reliability in wind turbine gears and bearings.

A lifespan of 20 years is envisaged for all common wind turbines, although an attempt is of course made to extend this by a few years or even up to 30 years. During this period of use, both the gearbox and the bearings are affected by wear, to the extent that these components must be replaced over the lifetime of the wind turbine (sometimes even several times). These replacements of components are associated with downtime and loss of generating capacity as well as significantly increasing operation and maintenance costs. The downtime to replace various wind turbine components, with gearboxes takes up to 14 days to replace.

This lubricant additive helps to significantly reduce or even prevent damage like white etching areas, false brinelling, macropitting, smearing and scuffing, corrosion, electric arc damage, whereby an application is recommended for both new and already damaged systems. The technology is an innovative lubricant additive with a protective and repairing effect, which mainly consists of phyllosilicates in the form of micro and nanoparticles. The particles use lubricant as a carrier to reach the rubbing metal surfaces and to coat damaged areas them by adsorption. The new, modified surface is optimized and protected from a tribological point of view, so that surface roughness, friction, wear and temperature in the system are reduced. This leads to a significant improvement in efficiency and lifespan. In addition to surface protection, the technology reduces friction and thus also the temperature in gearboxes and bearings.

This innovative technology has been tested in cooperation with several universities and colleges and is protected by corresponding patents. The technology uses to address such issues as pitting, run through marks, downtime damage and many other risk factors that can cause wind turbine breakdowns.

Technology in Action: Field Tests

For a meaningful evaluation of the application, it is necessary to analyze and to compare the steel surfaces in the system before and after the treatment. Replica set technology makes it possible to perform the surface analysis of gears or bearings by making imprints of the representative areas of the surface with high precision and reliability. The subsequent analysis of the imprints with light microscopy provides valuable tribological information about the surface condition.

Tooth Flank Surface Damage on a High-Speed Shaft

Figure 1 displays the tooth flank surface of a high-speed shaft in a wind turbine with a power of 1.5 MW. The first imprint (a) of the high-speed shaft was taken before the application of the lubricant additive. It shows running traces at the upper area and notable micro pitting at the middle and lower area.

The second imprint (b) was taken three months after the product application. The same area of the tooth flank is

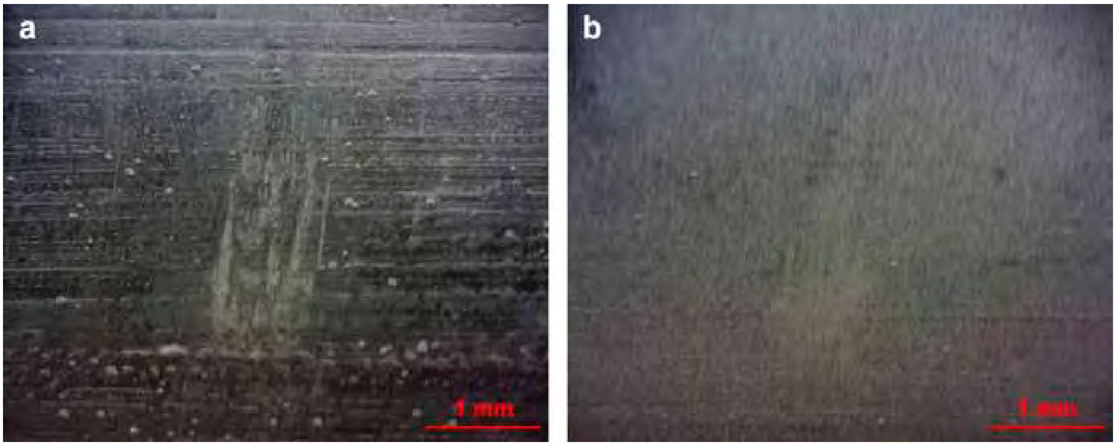


Figure 1:
Tooth flank imprints of the high-speed shaft in a wind turbine (1.5 MW) before (a) and 3 months after the application of the lubricant additive (b).

Figure 2:
Main bearing imprints of wind turbine GE (1.5 MW) before (left), 5 months after the application of the lubricant additive (middle) and 12 months after the application of lubricant additive (right)

clearly visible. The striking difference is that the micro pitting is repaired and there are no running traces. There is a significant improvement in the surface condition through the repairing and protective effect of the lubricant additive.

This surface modification ensures more homogenous load distribution in the system and in this way protects the surfaces. The optical analysis of the worn areas shows that the lubricant additive application was successful and achieved its aim: repairing and the protection of surfaces.

Main Bearing Damage

In this example we are showing a similar analysis of the main bearing in a wind turbine GE (1.5 MW).

To analyze the wear development over a period of one year, we made several imprints of the representative areas of the surface with high precision and reliability. For a quantitative evaluation of the application we measured the roughness within the track in the middle of the imprints. This provides valuable tribological information about the surface condition.

The roughness before the wind turbine was treated with the lubricant additive was Ra = 0.556 µm.

Five months after the application, the roughness was reduced by 28 % to Ra = 0.403 µm.

At the third measurement 12 months after application, we noticed a reduction of roughness within the track by 60 % to Ra = 0.225 µm.

The surface analysis clearly shows that the structure and roughness of the surfaces are significantly improved. That means less stress on the mechanical components and a substantial increase in the lifetime. Beside the significant improvement of the surface condition, a reduction in vibration was also observed.

Conclusion

Wind turbines form a cornerstone of the world's efforts to reduce carbon emissions from electricity generation. Wind turbine technology is maturing and prices are reducing but the technology still suffers from reliability issues. Gears and bearings are not the least reliable component in a wind turbine, but when they fail, they cause significant downtime and repairs can be extremely expensive.

The lubricant additive repairs existing damage in wind turbine gears and bearings and protects the system for the future. Through surface modification, roughness is significantly reduced, which leads to lower local loads and lower tribological stress. These effects provide a longer lifetime, better reliability, and higher efficiency – making wind turbines last longer.

ELECTRICITY GOVERNANCE ECOSYSTEM IN INDIA

Act, Policy and Rules

Electricity Act 2003

Adopted on 2nd June 2003 and Consolidates

1. The Indian Electricity Act, 1910
2. The Electricity (Supply) Act 1948
3. The Electricity Regulatory Committee Act 1998

Mandates Preparation of following guiding documents

1. National Electricity Policy and Tariff Policy – (Section 3) - by Government of India
2. National Electricity Plan once in five years – (Sec3) By CEA
3. National Policy of Rural Electrification - (Sec 4 & 5)
4. Grid Standards and Technical Standards – (Sec 73) by CEA
5. Grid Code (Sec 79) by CERC and State Grid Code - (Sec 86) by SERC

CENTRAL GOVERNMENT
Ministry of Power and Ministry of New and Renewable Energy

1. Administration of Electricity Act 2003
2. Administration of Energy Conservation Act 2001
3. To undertake such amendments to these Acts as may be necessary in conformity with the government policy objectives
4. Responsible for development of electrical energy in the country

CENTRAL ELECTRICITY AUTHORITY (CEA) (Sec 73)

1. Monitoring Performance
2. Advising the MoP on technical issues
3. Data Management/dissemination
4. Preparation of Technical Standards
5. Preparation of National Electricity Plan

APPELLATE TRIBUNAL FOR ELECTRICITY (SECTION 110)

To hear appeal against the orders of the adjudicating of the Commission

STATE GOVERNMENT
(State Energy Department)

1. Act as per the Electricity Act, 2003
2. Administration of Energy Conservation in the State
3. To undertake such actions as deemed fit in accordance with rules and policies
4. Responsible for development of electrical energy in the state.

REGULATIONS

CENTRAL COMMISSION (SECTION 76)
Central Electricity Regulatory Commission

1. To regulate and determine the tariff of central generating company and inter-state transmission system.
2. Issue license to inter-state transmission licensee and electricity traders for inter-state operations.
3. Adjudicate upon dispute involving generating companies and transmission licensee.
4. To specify Grid Code.

FORUM OF REGULATORS

Consisting of the Chairperson of the Central Commission and Chairpersons of the State Commissions.

The Chairperson of the Central Commission is Designated as Chairperson.

STATE COMMISSION – SECTION 82
Joint Commission – Section-83

1. To determine tariff generation, supply, transmission and wheeling of electricity, wholesale, bulk or retail within state.
2. Regulate electricity purchase and procurement process of distribution licenses.
3. Facilitate intra-state transmission and wheeling of electricity.

IMPLEMENTATION

REGIONAL POWER COMMITTEES - BY CENTRAL GOVERNMENT – SECTION 2 (55)

Facilitation the integrated operation of the power system in that region

NATIONAL LOAD DESPATCH CENTER (NLDC) SECTION-26

Power System Operation Corporation Ltd. (POSOCO)

Apex body for grid operation, monitors and schedules inter-regional and trans-national electricity exchange

CENTRAL TRANSMISSION UTILITY

POWER GRID CORPORATION OF INDIA LIMITED

1. To discharge all functions related to planning and co-ordination relating to inter-state transmission system.
2. To ensure development of an efficient, coordinated and economical system of inter-state transmission lines for smooth flow of electricity from generating stations to the load centres.

STATE TRANSMISSION UTILITY

Designated by State

1. To discharge all functions related to planning and coordination relating to intra-state transmission system
2. To ensure development of an efficient, co-ordinated and economical system of intrastate transmission lines.

REGIONAL LOAD DESPATCH CENTER (RLDC) SECTION-27

1. Managed by Central Government Company = POSOCO Ltd.
2. Optimum scheduling and dispatch of electricity within region.
3. Monitors grid operation within region.
4. Keep accounts of electricity transmitted on regional grid.
5. Operate as per grid standard and grid code.

Central Advisory Committee: Constituted As Per Section 80

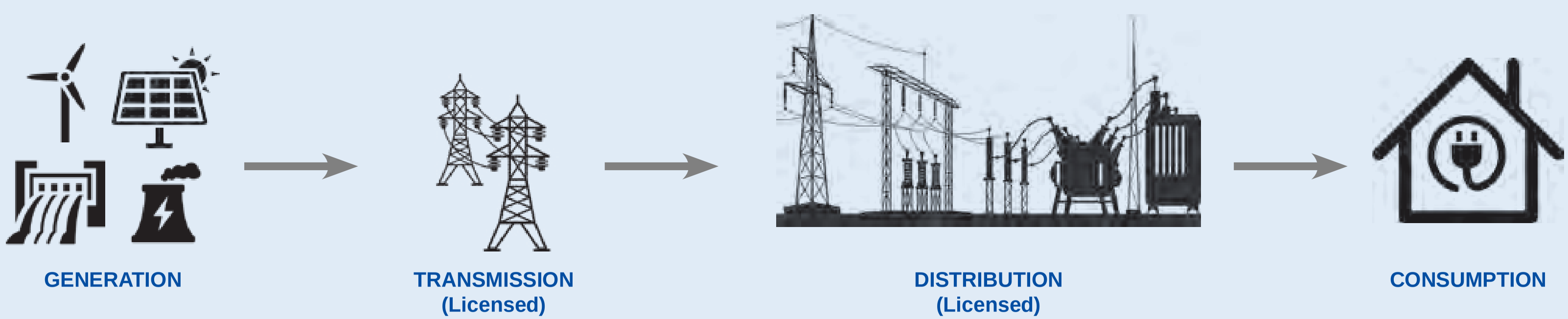
STATE LOAD DESPATCH CENTER (SLDC) SECTION-31

1. Managed by state government or its company.
2. Optimum scheduling and dispatch of electricity within state.
3. Monitors grid operation within state.
4. Keep accounts of electricity transmitted on state grid.
5. Operate as per grid standard and state grid code.

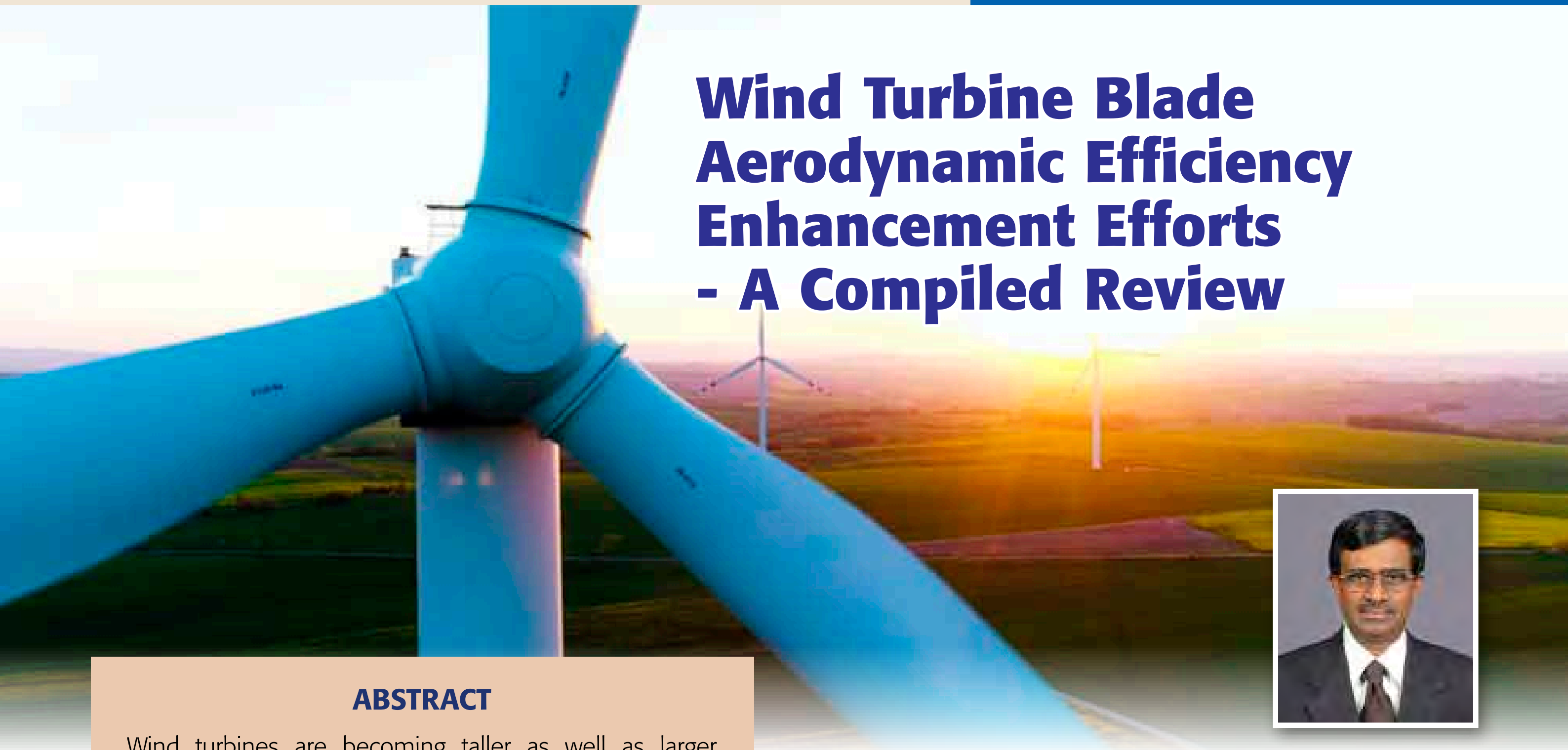
State Advisory Committee: Constituted As Per Section 87

SUPPLY

ELECTRICITY MARKET – POWER EXCHANGE, ELECTRICITY TRADERS (LICENSED)



Disclaimer: Information as given above is indicatives only and should not be used for legal purpose.; For details please refer Electricity Act 2003. Prepared by: **P.K. Agrawal**, 19 October 2020



Wind Turbine Blade Aerodynamic Efficiency Enhancement Efforts - A Compiled Review

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ABSTRACT

Wind turbines are becoming taller as well as larger in diameter day-by-day with the advent of newer technologies to exploit more energy from the abundant wind available all over the world. Three decades of research in wind energy sector in the Americas' and more rigorously practical design implementations in Europe have opened up more focus in several related areas of wind turbine design techniques, choice of material composites, as well as passive and active lift augmentation in the design of wind turbine blades It has been theoretically proven that doubling of rotor diameter has literally quadrupled the amount of wind energy generated, thus reducing the CAPEx, OPEx and LCOE per unit of electricity, towards meeting sustainable uninterrupted power for all. This article reviews the historical innovative efforts by scientists around the world to enhance the aerodynamic efficiency of wind turbine blades, with an emphasis to gear up fundamental research under "Atmanirbhar Bharat" in India, India being a leading global manufacturing hub for wind energy equipment, with economy, efficiency and international accredited quality.

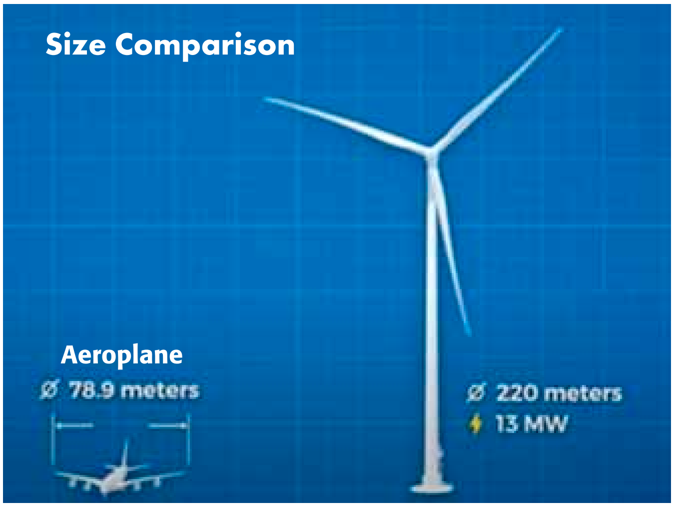
Introduction

On 9th January 2021, India times reports latest developments in offshore wind farming in the United States of America off the coast of Massachusetts by M/s Vineyard Wind. Vineyard Wind CEO Lars T. Pedersen, speaking in a press release at the end of last year, explained just how important this progress is: He said: "The selection of GE as our preferred turbine supplier means that a historic American company will play a vital role in the development of the first commercial scale offshore wind power in the US." The wind farm is going to use the largest capacity, high efficiency wind turbine blades GE's Haliade-X (Figure 1) of LM Blades, Denmark which has been acquired by General Electric, USA in order to leap frog their wind energy development around the world. It can be seen the EWEA predictions for beyond 2020 had been 250m diameter rotor blades which is close to becoming reality with already the giant blade of 107m with diameter at 220m.

Unlike the olden days today's young and enthusiastic researchers are able to access several public domain research papers and reports to fine tune their understanding of the gaps in the design of wind turbine blades and to jump start with new software, hardware and new multidisciplinary structural materials and analytical CFD flow simulation tools aided by wind tunnel studies even though challenging, with severe scale limitations. The brief paper is an attempt to review blade design developments for the past few decades, from "Googled" articles/reports, to trigger indigenous innovative industry funded Government initiated research gearing towards "AtmaNirbhar Bharat" with the well-established WTG manufacturing global industrial hub in India.

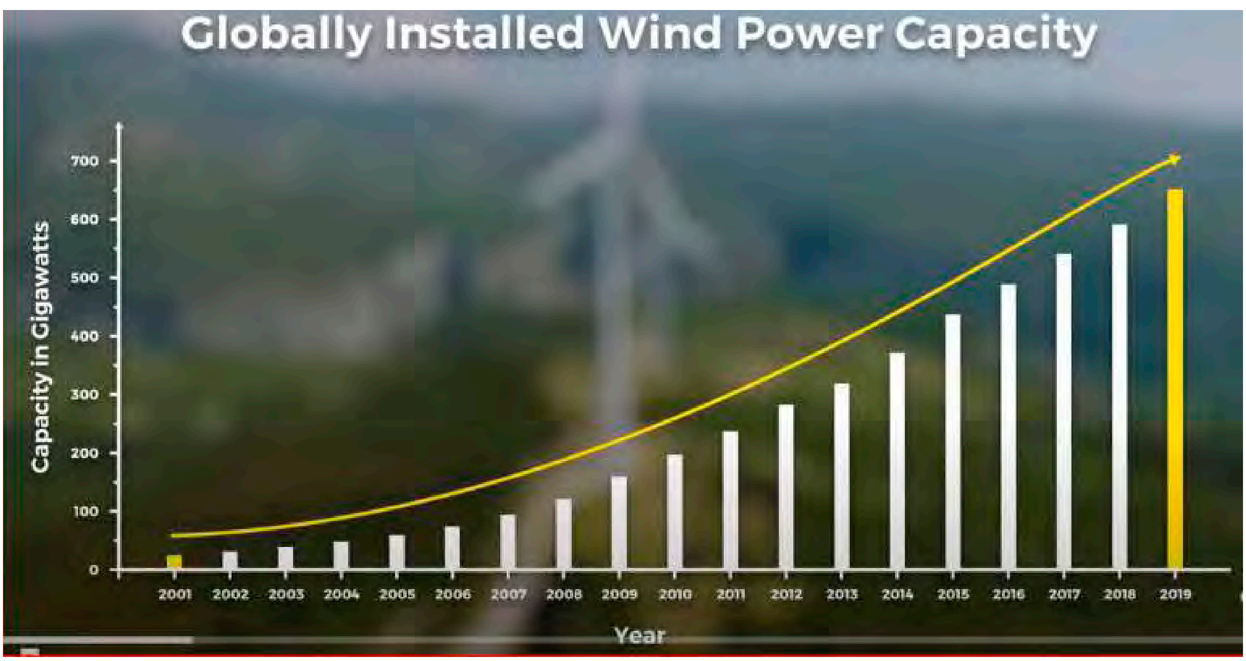
In the 1990s

This excellent report-Assessment of Research Needs for Wind Turbine Rotor Materials Technology, Washington, DC[1] has foreseen and initiated several developments to improve wind energy capture from kinetic energy of wind. The report had been quite comprehensive in the sense, it had dwelt most of the fundamental design concepts, composite materials manufacturing processes, envisaged the possible modes of failure of blade composites in fatigue. As observed in Figure 2, it was identified that full span pitch control has been one of the easy hanging fruits for most of today's wind turbines when compared to fixed pitch with stall controls and the more sophisticated partial-span pitch, Aileron, and boundary layer controls for improving the efficiency of wind turbine blades. The essence is increasing the lift as well as ratio of lift to drag, while managing atmospheric turbulence in the boundary layer wind.



While proposing the advanced design innovations which are needed, classified and highlighted the thin and thick aerofoil families and their Characteristic design needs (Figure 3). The Committee on Assessment of Research Needs for Wind Turbine Rotor Materials Technology, Energy Engineering Board of Commission on Engineering and Technical Systems at National Research Council of National Academy Press also explained the need to concentrate on the modes of fatigue failures while having the primary and vital focus on high ratio of strength to weight (Figure 4). The modes involving crack coupling and interfacial debonding and the delamination phases of fatigue seeming to be more than 50% of the entire fatigue life which is a challenge even today for wind turbine blade designs.

The committee also suggested various materials for wind turbine blade making. The world has progressed a long way to beat the challenges to forge ahead with several features to boost the efficiency of wind turbine blades. The decade of 1990s witnessed fast track developments and scaling up not only wind



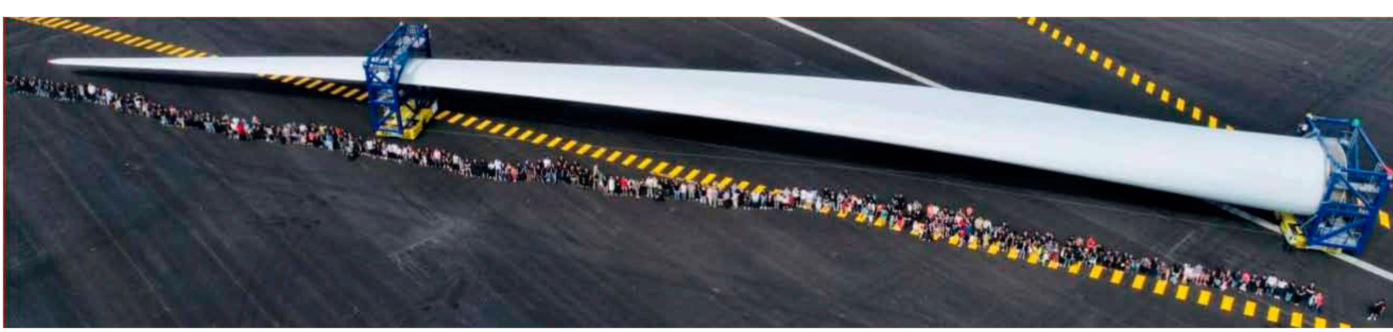


Figure - 1

Globally Installed Wind Turbine Capacity and EWEA Predicted Diameters (220m)
Largest Blade is getting the certification and challenge of logistics is real

(Sources Acknowledged: https://www.youtube.com/watch?v=wr7QZ364jPY (Real Engineering), https://www.ge.com/news/reports/blade-of-glory-a-critical-offshore-wind-turbine-component-passes-a-key-milestone)

power capacity addition, higher capacity machines upto 3 to 5MW/WTG with taller hub-heights, as well as larger rotor diameters both in the USA as well as more swiftly in the Europe. There had been several innovative developments in the wind turbine blade development around the world; however this key review report[1] has only been used to introduce the domain of focus in this review.

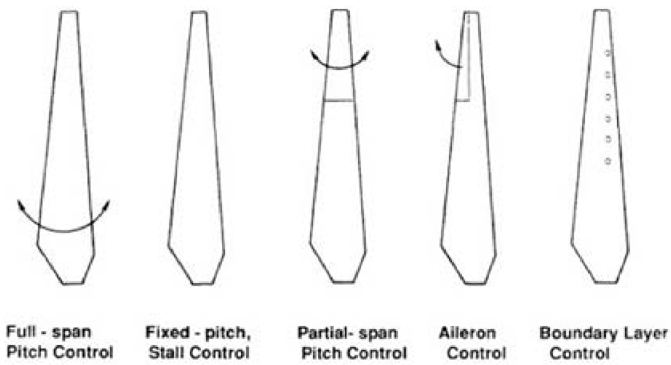


Figure - 2

Wind Turbine Blade Efficiency Enhancement Methods[1]

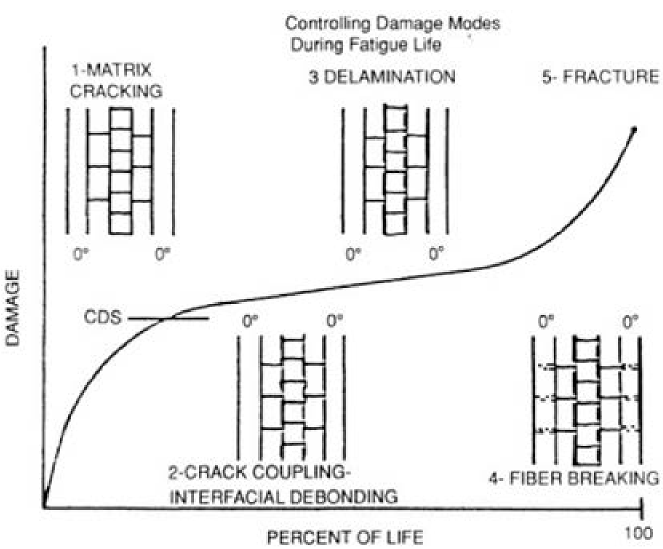


Figure - 4

Identified Fatigue Failure Modes in Layered Composite Wind Turbine Blades[1]

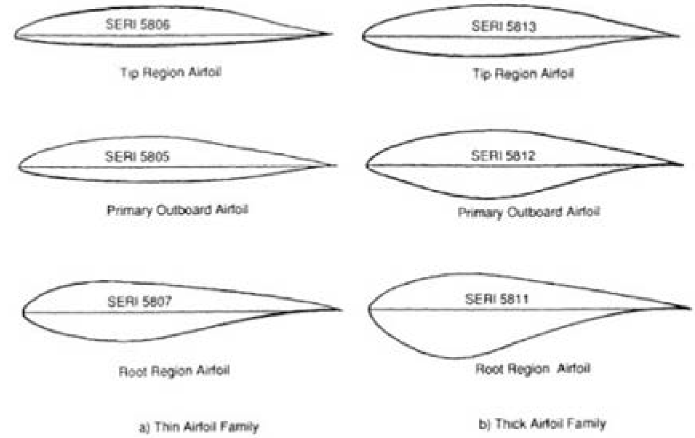


Figure - 3

Classified Shapes for Thin as well as Thick Aerofoil[1]

In 2000-2010

In this decade, several independent as well as collaborative research[2-11] were observed in active (AFC) as well as passive flow control (PFC) leading to efficiency of wind turbine blade's energy capture capability. Christian Bak's[2] aerodynamic key parameter sensitivity studies and Sanderse's[3] dealings of aerodynamics of wind turbine wakes are two core contributions.

In 2005, publication of AERODYN theory manual described the basis of public domain software developed by NREL, USA[4]. "AeroDyn was a set of routines used in conjunction with an aeroelastic simulation code to predict the aerodynamics of horizontal axis wind turbines. These subroutines provide several different models whose theoretical bases were described in the manual. AeroDyn contained two models for calculating the effect of wind turbine wakes: the blade element momentum theory and the generalized dynamic-wake theory. Blade element momentum theory is even now the classical standard used by many wind turbine designers and generalized dynamic wake theory was the then a more recent model useful for modeling skewed and unsteady wake dynamics. When using the blade element momentum theory, various corrections were available for the user, such as incorporating the aerodynamic effects of tip losses, hub losses, and skewed wakes. With the generalized dynamic wake, all of these effects had been automatically included. Both of these methods were used to calculate the axial induced velocities from the wake in the rotor plane. The user also has the option of calculating the rotational induced velocity. In addition, AeroDyn contained an important model for dynamic stall based on the semi-empirical Beddoes-Leishman model. This model had been particularly important for yawed wind turbines. Another aerodynamic model in AeroDyn was a tower shadow model based on potential flow around a

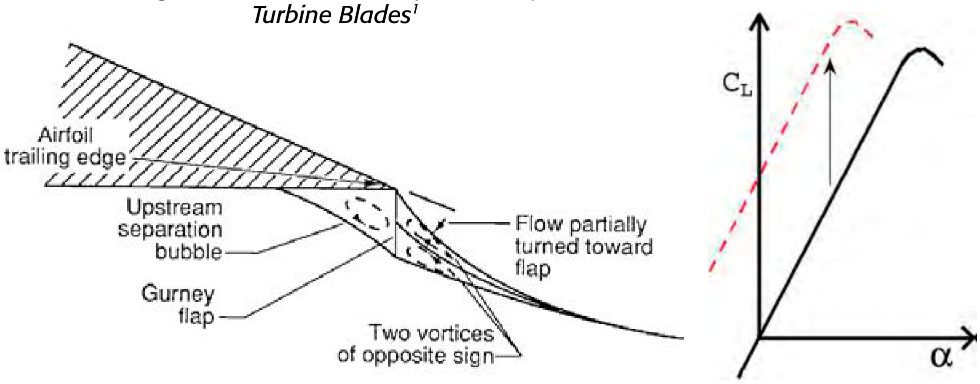


Figure - 5

Concept of PFC Technique: Gurney Flap at Trailing Edge (Van Dam 2000 UC)

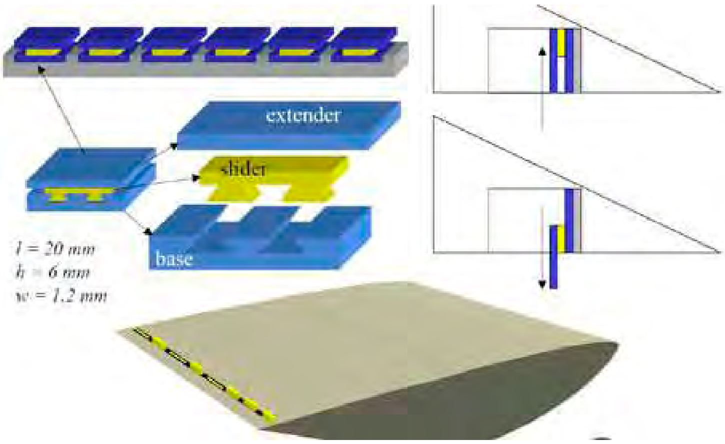


Figure - 6

Concept of MEMS Microtab[5-6]
Flow Control Van Dam (2000) UC

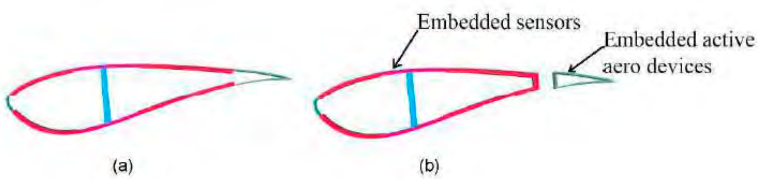


Figure - 7

Traditional Blade (a) and
AFC Devices Conceptual Design (b)[5,6]

cylinder and an expanding wake. Finally, AeroDyn then had the ability to read several different formats of wind input, including single-point hub-height wind files or multiple-point turbulent winds." Passive flow control (PFC), is normally used to improve performance of turbine, mitigate dynamic loads, and thus reduce stress levels. The techniques extensively adopted include: Laminar flow control, Passive porosity, Riblets, Vortex generators, Stall strips, Gurney flaps, Serrated trailing edges, Aeroelastic tailoring, Special purpose airfoils (restrained max. lift; high lift; blunt trailing edge). One of the techniques is Gurney flaps for boosting Lift at a lower angle of attack (Figure 5).

While there are several authors carried out in a wide spectrum of AFC and PFC devices for wind turbine blade designs[5-6], Dale Berg et.al. (2006) worked in the concept of Gurney flaps[7].

Another concept proposed by Yen NakaFuji & Van Dam (2000) is based on Micro-Electro-Mechanical (MEM) devices, which is Microtab (Figure 6 and 7) has most advantages such as: Small, simple, fast response, retractable and controllable, lightweight, inexpensive, Two-position "On-Off" actuation, low power consumption, no hinge moments, expansion possibilities (scalability), do not require significant changes to conventional lifting surface design (i.e. manufacturing or materials).

Another popular tip loss reduction technique had been winglets modifying the flow conditions at the tip of the blade which many of us would have noticed in some of the aircrafts as well. Three typical winglet designs have been compared and discussed[9]. In Figure 8 the top images provide design parameters for winglets. The blue, red and green colored surfaces at the tip of the blade are the three typical shapes of winglets and the yellow is the original tip of the blade.

Winglets generate micro-vortices in two opposite directions reducing load-effects as the tip of the blade cuts through the wind turbulence.

Christian Bak in 2007 has theoretically compared Cl/Cd ratio, Cp and AEP of different types of aerofoil blade profiles[10] with a focus on optimum wind turbine performance. As one of the most often sought FAQ on what would be the number blades effect on the Cp and wind turbine performance, a study had been reported in 2009[11].

In 2008, SANDIA report[5] has described as many as fifteen active flow (load) controls devices which can improve the efficiency of energy capture by enhancing the lift coefficient (Table.1)

In 2009 in a review report on the study of wind turbine wakes[3] by Sanderse, "in order to reduce power losses and to improve the lifetime of the blades it was pointed out that it was necessary to obtain a good understanding of the behaviour of wind turbine wakes in wind farms. Such an understanding could be obtained by numerical or experimental simulation. Three tasks can be defined for simulating wind turbine wakes: 1: Calculating rotor performance and park efficiency; this requires the time-averaged velocity profile behind a turbine; 2: Calculating

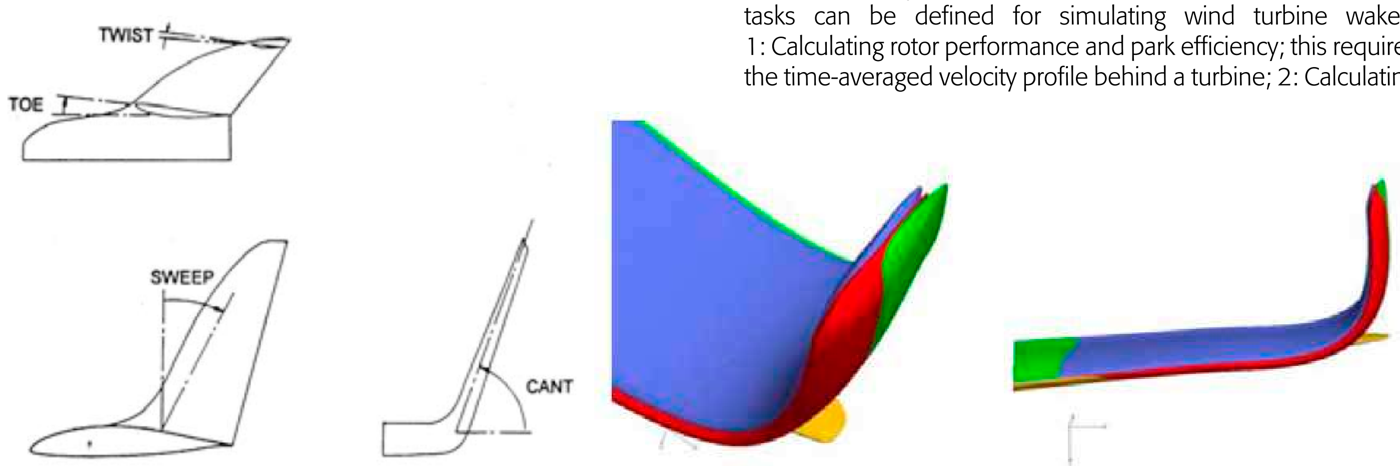


Figure - 8

Three Typical Configurations of Winglet Designs Studied[9]

S.No.	Devices	Geometric (G) Fluidic (F) Plasma (P)	Leading Edge (LE) Trailing Edge (TE) Mid-Chord (MC)	Inc. Lift (I) Dec. Lift (D) Delay Stall (DS)	Steady (S) Unsteady (U)
1.	Traditional Trailing Edge Flaps	G	TE	I/D	S/U
2.	Nontraditional Trailing - Edge Flaps	G	TE	I/D	S/U
3.	Microtabs	G	TE	I/D	S/U
4.	Miniature Trailing - Edge Effectors	G	TE	I/D	S/U
5.	Microflaps	G	TE	I/D	S/U
6.	Active Stall Strips	G	LE	D	S
7.	Vortex Generators	G	LE	DS	S
8.	Blowing and Suction	F	LE / TE	DS	S/U
9.	Circulation Control	F	TE	I/D	S
10.	Plasma Actuators	P	LE	DS	S
11.	Vortex Generator Jets	F	LE	DS	S/U
12.	High-Frequency Micro Vortex Generators	G	LE	DS	U
13.	Synthetic Jets	G/F	LE	DS	U
14.	Active Flexible Wall	G	LE	DS	U
15.	Shape Change Airfoil	G	MC	I	S/U

Source: *Acknowledgement: SANDIA Report 2008*[5]

Table - 1*: Classification Chart used to label each AFC device*

blade loading of turbines operating in wakes of other turbines and the fluctuations, in the electrical energy output; this requires the turbulence fluctuations and the turbulence intensity in the wake and 3: Calculating wake meandering; this requires that large atmospheric eddies are taken into account.

There are a number of reasons for focusing[3] on numerical simulation instead of on experiments:

- Full-scale, good quality experiments are costly and have been limited mainly to provide Global information on the flow field. Computational Fluid Dynamics (CFD) can provide detailed information both upstream and downstream of the turbine.
- Due to the variability in atmospheric conditions it is difficult to find the mutual influence of turbines on each other.
- Optimization of a wind farm layout in an experimental setting is almost impossible.

However, CFD computations of wind farms face other difficulties:

- Accurately modelling both the flow over the turbine blades and the flow in the near and far wake requires massive computer resources, due to the unsteady, turbulent character of the flow. For most turbines the optimal operating condition is close to stall. The flow field exhibits scales that range from the size of small eddies in the boundary layer on the blade to the distance between wind turbines. Simulating the turbulence in the flow accurately and preventing artificial diffusion is an on-going challenge.
- The rotation of the rotor blades leads to severe problems in constructing a computational grid.

Having clearly driven by the potential of cost effective as well as time effective proof-of-concept studies with CFD (CFD - Computational Fluid Dynamics though "not-alternate to wind tunnel simulations," but, a convenient preliminary NUMERICAL wind tunnel studies), quite a number of contributions[8-11] have been published, on numerical simulations of flow around winglets as well as influence of number of blades on wind power performance.

From 2011 to 2020

Based on the long research proposal of European high level committee[26], quoted discussions on the three important areas of wind energy research viz. materials & structures, wind and turbulence, and aerodynamics were presented in 2019[25] by my earlier communication to Indian Wind Power two years ago, with technology way forward in India. The contributions from Europe seem to live up to the planned activities[12-26] irrespective of corona lockdowns. Some of which would be highlighted in this section.

The authors[12-13] have made use of modern tools like CFD as increased computational power is now available in desktop server systems, to compare lift and drag using 3D modelling capabilities of the codes (Figure 9). The Masters thesis in 2011 has focused on use of commercially available codes with a few airfoil profiles and compared the results discussed.

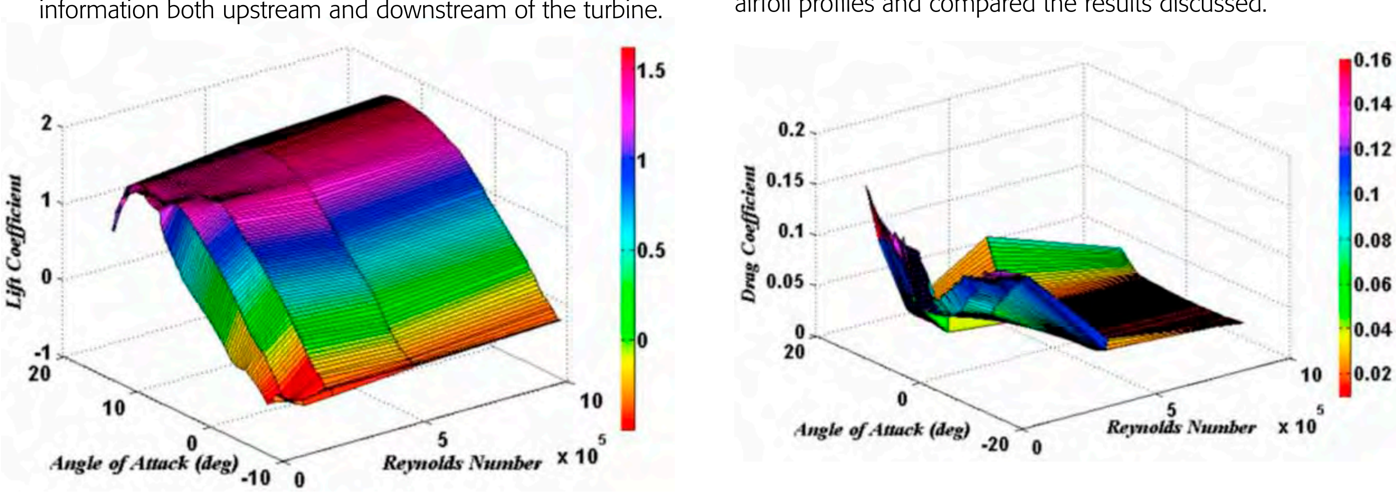


Figure - 9: *Comparative Studies on Lift and Drag through Parametric Study*[12]

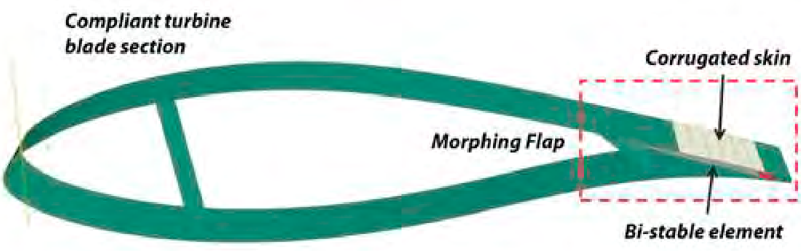


Figure - 10

Innovative Blade Design with Morphing Flap[18]

The PhD thesis[17] from T.U. Berlin, Germany, is an excellent state of the art work, which is of highly practical applications for aero engineers with innovative bent of mind. It covers the entire spectrum of methods and concepts of passive and active flow control of wind turbine blades with excellent review, identification of gaps and clear description of alternative technologies towards blade efficiency enhancements with analytical, experimental as well as CFD simulations of state-of-art practical applications. Innovative ideas and options for AFC device selection depending on airfoil type are additional information for the young researchers and blade designers. The latest innovation in blade technology is morphing tail end flap[10] with bi-stable temperature sensitive and corrugated lay-up of composites[18].

The authors have introduced a passive mechanism for alleviating loads on turbine blades utilizing selective compliance morphing structures. Specifically, a morphing flap exhibiting two markedly different stiffness states is designed: a stiff state to maintain high lift and energy generation and a directionally flexible state for passive load reduction. "The monolithic topology of the proposed structure featuring embedded bistable beams requires no additional systems and is geometrically scalable, allowing for introduction into different blades sizes. The passive nature of the presented load alleviation mechanism does not require the use of complex sensing or closed-loop control systems. A simple actuator can be utilized to reset the bistable element to its energy-generating state. These characteristics are crucial to ensure cost-effectiveness for both construction and maintenance of the proposed mechanism", as claimed and concluded by the authors[18].

M/s Vestas the leading technology company has offered the users their ECO (extended cut out of rotor) feature (Figure11) which will facilitate smoother cut out of the wind turbine in high winds so that the transition can be utilized to enhance the AEP of the wind turbine. Several innovative ideas are presented in 2019 as European perspectives of airborne wind energy, floating offshore wind concepts, smart rotors and lists a possible research systems and scale-up options (Table 2) of the same[20]. Many of these wind systems might take another decade to get deployed commercially.

Another interesting application is by introducing synthetic jets to boost the lift coefficient further and actively manage the wind turbulence[21]. "It gives an overview of active flow control techniques with a specific focus on the application and use of the piezoelectric synthetic jet for vibration reduction of small-scale wind turbine blade models tested in a wind tunnel. Using the techniques presented, the global flow field over the blade was altered such that flow separation was mitigated. Consequently, this resulted in a significant decrease in the vibration of the blade. Particle image velocimetry (PIV) was used to quantify the flow field over the blade. Using synthetic jets, the flow over the blade was either fully or partially reattached, depending on the angle of attack. Current and future research in this field has evolved to understanding and controlling realistic 3D vortex flows typical of actual wind turbines utilizing scaled-down rotor platforms. To this end, the author presents the design and operation of a rotor test tower with custom blades embedded with synthetic jet actuators aimed at investigating multi-scale blade tip vortex interaction and breakdown that may lead to blade vibration and noise reduction."

Recent articles[22-23] focus on structural and material features that provide the wind turbine blades the required low weight to strength as well as dynamic characteristics under the random

Technology readiness level and power scale assessments for the different FETs identified

Technology	TRL (2017) and TRL trend	Power (2017)	Scaling up target
Airborne wind energy	TRL = 3-5 Trend: Slow	100 kW nominal power	~ MW
Multiple drone systems (MD AWES)	TRL = 2-3 Trend: Slow	N. a.	Up to ~10 MW
Autonomous take-off and landing systems	TRL = 2-3 Trend: Slow	N. a.	N. a.
Offshore Floating wind concepts	TRL = 4.9 Trend: Slow	6 MW	10 MW
Floating hybrid energy platforms: a) wind-wave and b) wind-wind systems	TRL = 1-5 a): 1-5; b): 3-4 Trend: Slow	100 kW	10 MW
Smart rotors: a) Bend Twist Coupling; b) Segmented Ultra Morphing Rotor; c) Vortex generator; d) Blades with movable parts; e) Circulation control systems; f) Active control systems	TRL = 2-7 a): 5-7; b): 4; c): 5-6; d): 2-4; e): 2-4; f): 2-3 Trend: Average/Fast	100 kW ÷ 12 MW	~ 10-50 MW
Wind induced energy harvesting from aeroelastic phenomena: a) flutter and galloping-based devices; b) vortex induced vibrations-based devices	TRL 2-4 a):2-3; b): 3-4) Trend: Slow	~ W (2W/m)	~ kW
Wind turbine with tip-rotors	TRL = 1-2 Trend: Slow	N.a.	N.a.
Unconventional power transmission for wind turbine rotors	TRL = 1-7 Trend: Slow	7 MW	~ 100 MW
Multi-rotor system (MRS) wind turbines	TRL = 2-6 Trend: Fast	900 kW	≥20 MW
Diffuser augmented wind turbine	TRL = 5-6 Trend: Fast	10–100 kW	≤1 MW
Future supporting technologies: a) Alternative fixed bottom support structures; b) Self-rising towers; c) New materials for towers and support structures	TRL = 2-8 a) 2-8 b) 2-5 c) 2-8 Trend: Average	N.a.	a) 30 MW b) 30 MW c) N.a.
Modular HVDC generator	TRL = 3 Trend N.a.	45 kW	N.a.
High-fidelity multi-scale integrated models for complex wind flow	TRL = 3 Trend: Slow	N.a.	N.a.
Knowledge from wind energy databases	TRL = 3 Trend: Average	N.a.	N.a.
Innovative blade manufacturing techniques and materials	TRL ≤ 3 Trend: Slow/Average	N.a.	N.a.

Note: N.a.: Not applicable or Not available.

Table - 2*: Technology Readiness Levels of Research Systems[20]*

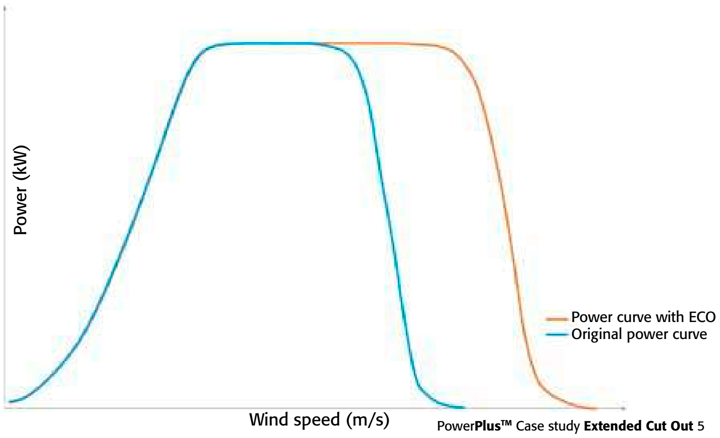


Figure - 11

Extended Cut Out for Smooth Cut Out and Higher Energy Production[19]

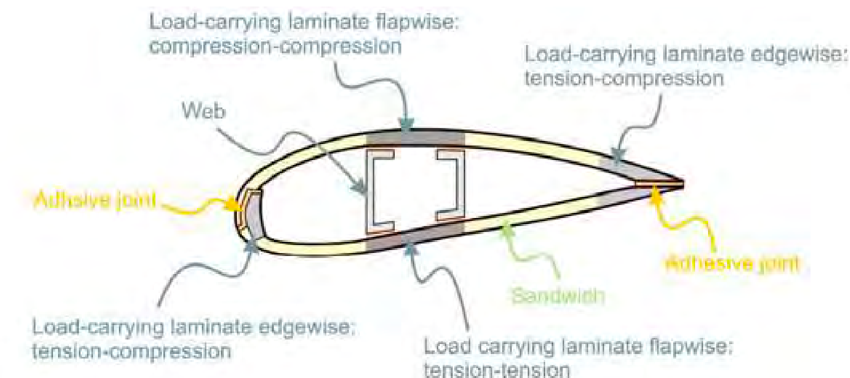


Figure - 12

Typical Schema Explaining the Blade Local Stressed Regions[23]

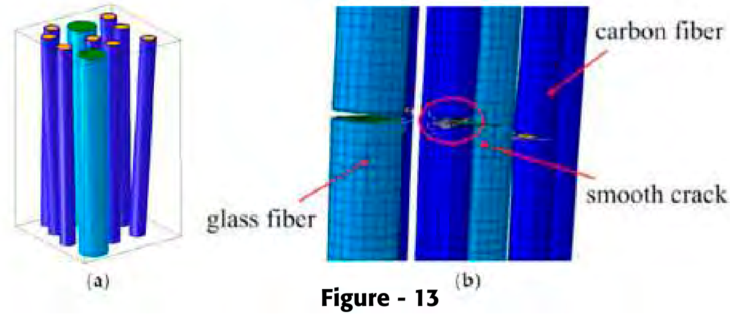


Figure - 13

Numerical Micromechanical Simulation Hybrid Glass/Carbon Fiber Failure[23]

dynamic loading (Figures 12 and 13) such as fatigue, which are highly localized phenomena ranging from low cycle high stress range to at times high cycle low stress range. In Figure12 we get a quick look at locations of cross-section of blade resisting a variety of stress cycles due to random and unsteady wind loading. Later Cemil Yigit in 2020 published an air ducted wind turbine blade design based on analytical and experimental studies including CFD simulation with encouraging results (Figure14) on higher power coefficient Cp[24].

In Figure 15 a conceptual sketch is provided by Victor Maldonaldo[21] on three types of AFC devices (a) a plasma technique which has external and embedded electrodes for effecting profile modifications based on thermal behavior of composite blade lay-up, (b) actuator controlled trailing flap and (c) ducted air jet (vortex generators), used in WT-blades.

In Figure 16, we appreciate the work[22] of embedded sensors to increase the damage tolerant structural monitoring of very large composite and hybrid (glass/carbon) fibre blades specially in the offshore environment (having very low accessibility when issues flare up).

The complexity arises in the scales of matrix composite and fibre which are in micrometers, while the blade sub-structures will be in few mm to m, the blade itself as well as floating platforms in 100s of meters. However these are getting affected by wind in kilometers of fetch, as well as in windfarms few kms of turbine spacing given the fact that both hub heights as well as rotor diameters are increasing day by day (Figure17).

The larger sized rotor enables significant reduction in levelised cost of energy LCOE (Figure17) as it is capable of operating for longer periods even though at lower RPM.

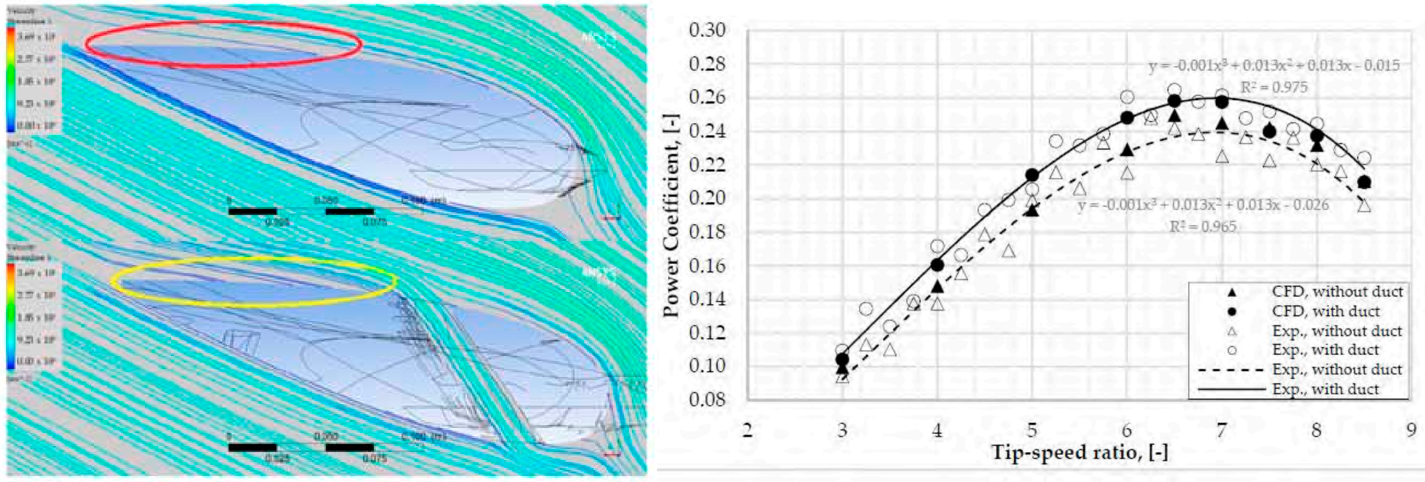


Figure - 14

Without and With Air-Duct Stream Lines Enhancing Power Coefficient[24]

Discussions and Way Forward in India

Materials and Structures for Blades

From the discussions that are initiated earlier[25] based on long term paradigm shift proposed by Europe[26], in the last three decades since 1991[1] there has been very many studies in fundamental characterization of required materials and structures that can be used to design and manufacture wind turbine blades all over the world. As a result from glass fibre reinforced plastics to carbon fibre, carbon nanotubes, variety of epoxy resin composites, wood epoxy mixed lay-ups, and recently smart blade materials are being used either in isolation or in combination as in hybrid blades. Fundamental research on blade making polymer composite materials and resins is not being pursued in a massive scale in India, excepting the CSIR-NAL laboratory which has an exclusive aerospace material research division.

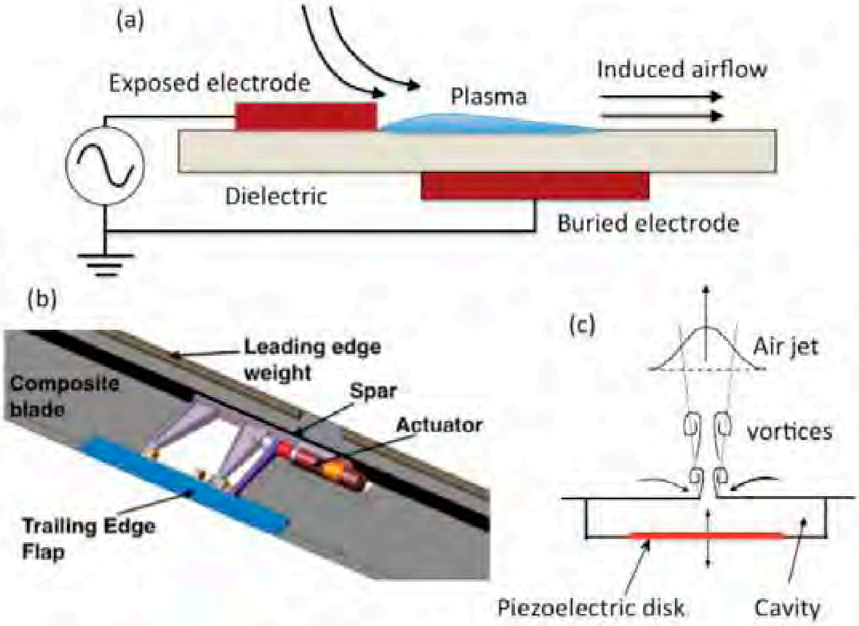


Figure - 15

Active Flow Control Devices with Synthetic Jet Vortex Generators on Blade[21]

Wind and Turbulence on Blades

With National Institute of Wind Energy, Chennai, India spear heading the measurement campaign for wind resources with taller towers and having got the expertise of meteorological macro/meso scale modelling, along with specific knowledge on microscale turbulence, India is almost on par with rest of the world in terms of reliable resource estimates and energy production forecasting and augmentation. Yet, the stated[25] spatio temporal analysis of simultaneously measured multi-stations (geologically spaced) wind time history data is yet to see the lime light of fruitful results for effective management of AEP uncertainties.

Aerodynamics of Blades

Despite the nano, micro, and macro level scale effects in the design of blades and modelling flow control over the blades and rotors, the access to recent researchers to numerical wind tunnel such as CFD simulations has given rise to studies mostly in laboratory scale blades/rotors. With the advent of high powered desktops the CFD applications have increased, but the results have not been put to practice by industry. A blessing in disguise could be that at least four corporates viz., General Electric

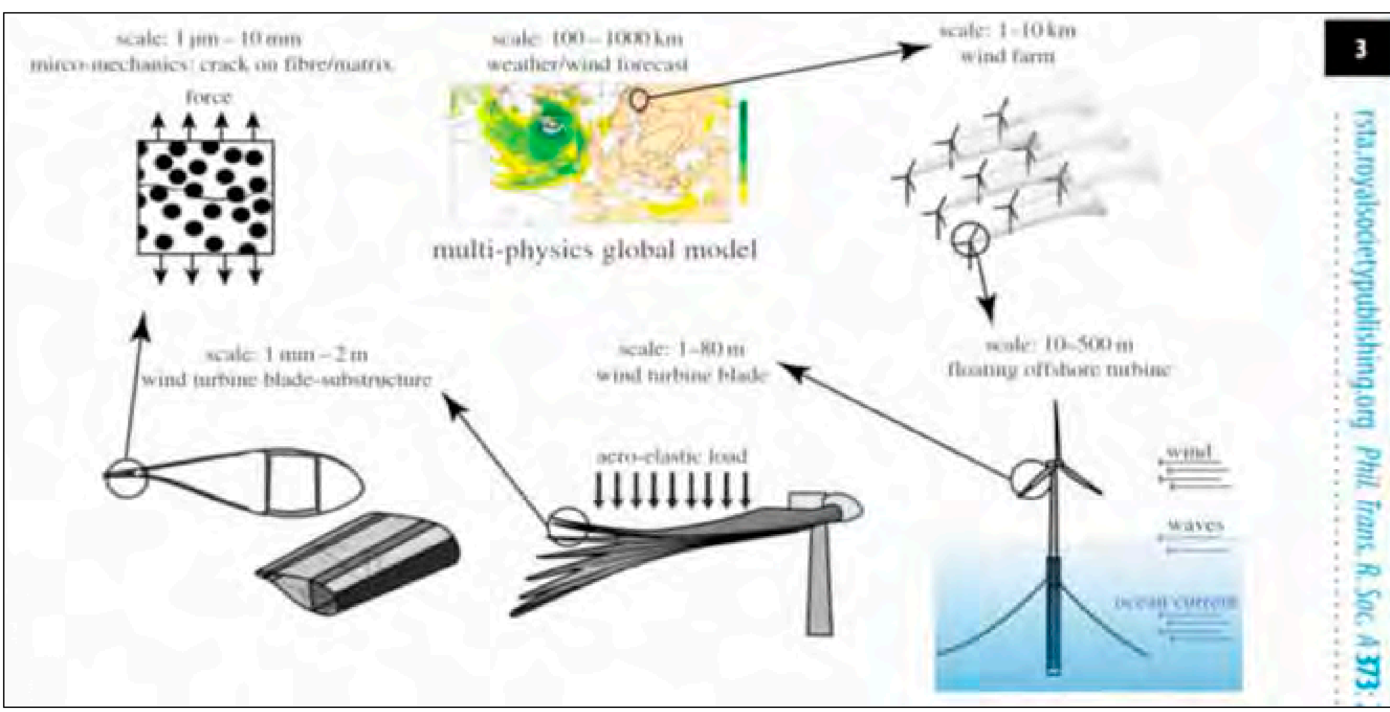


Figure - 16

Structural Monitoring of Blade in Scales of Micrometer to Kilometers[22]

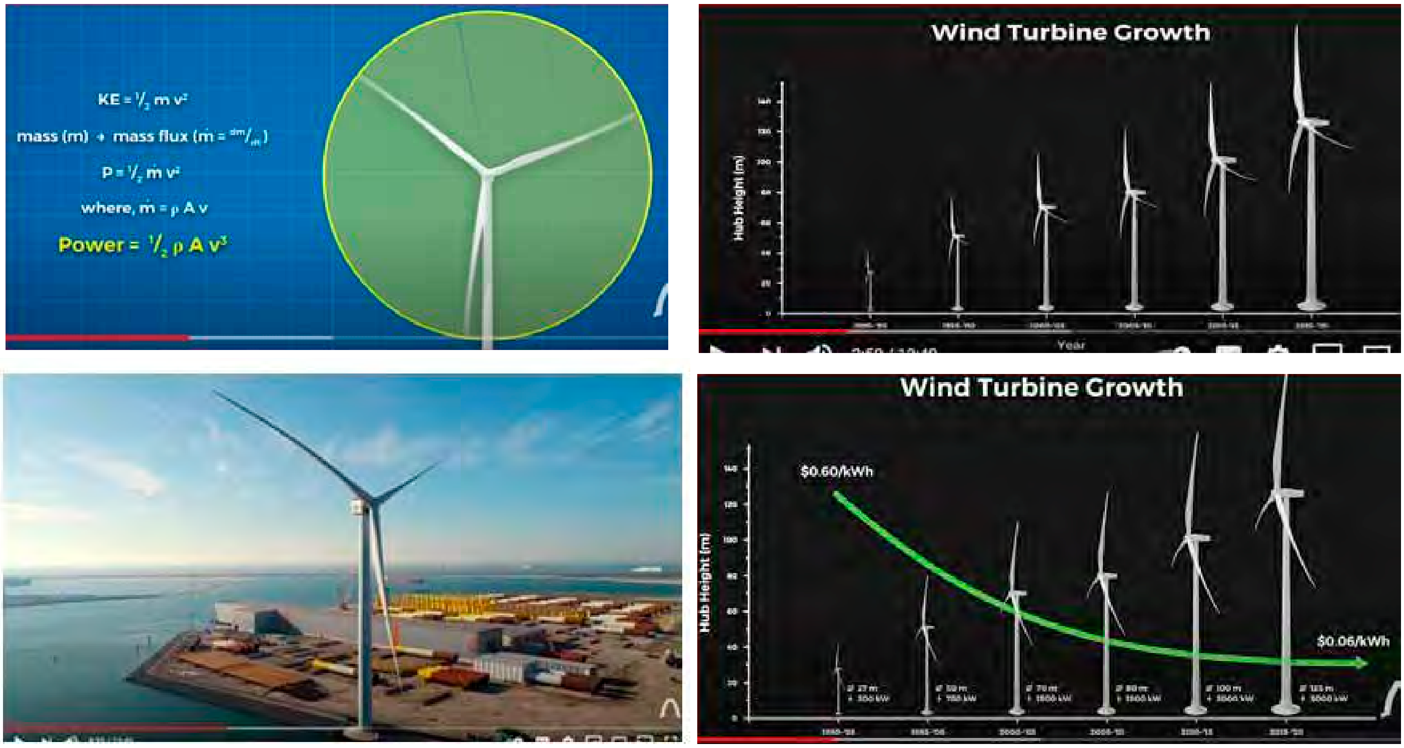


Figure - 17

The trends of Hub Heights (120+) and Associated LCOE Reduction
(Source Acknowledged: https://www.youtube.com/watch?v=wr7QZ364jPY (Real Engineering))

USA, Siemens Germany, Vestas Denmark and LM Wind Power, Denmark have their global research and development centers spread across India, especially with reference to wind turbine blades, rotor and integrated WTG design systems appropriate to India.

Conclusions

For a country like India, where the targets for renewables are set to 175GW by 2022 and 450GW in the future, an industry led consortium strongly supported by "AtmaNirbhar Bharat" policy needs a tremendous push in terms of scaling up the funding and funds for compatible capable young innovative multi-physics and multi-disciplinary engineering teams. As the IPR regime in this sector is highly competitive, a frame work such as ISRO or Department of Atomic Energy (DAE) in India is essential to innovate in the niche wind energy sector.

It is even more significant for wind industry to invest in knowledge creation through gap-analysis in this vital sector, for effective and efficient use of wind resources in India. Indigenously redesigned carter wind turbine blade with 300kW was performing with higher efficiency has been proved on ground by CSIR-SERC-CWET collaborative project. It could not be scaled up further for India specific (tropical and dusty low wind conditions) wind turbine blades and rotors in MW regime, is because of none of the OEM/manufacturing industry was in collaboration, even though analytical design, modelling and composite material design and tooling technology was available.

As a last word based on experience there is no dearth of funds, manpower, knowledge, but what is lacking is the synergy between Industry, academia and high profile research laboratories with adequate manpower and infrastructure.

Disclaimer: *The article is essentially a review article from most of available open sources and does not reflect the author's original contributions. The suggestions and recommendations based on observations are author's own, and not a constituent of any state or central/federal governmental policies. The sources have been duly acknowledged, being used as only compiled information dissemination through an industry published journal, with the limited review of accessible public domain documentations. The author is solely responsible for the communication of facts and figures in an "as-is-where-is" condition with his present level of understanding. The readers are encouraged to refer to the references for detailed knowledge.*

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Snippets

India gets Central Transmission Utility of India

India has created a central power transmission utility namely Central Transmission Utility of India, separating the business from state-run Power Grid Corporation of India (PGCIL) on 31st December 2020. It has been incorporated and a certificate of incorporation had been issued for the same hiving off of electricity transmission system planning business from PGCIL had been a long pending demand of the industry for fair bidding of transmission lines. The move will help PGCIL diversify to other businesses and comes just in time when the government has kicked off a power distribution programme starting with the union territories.

(Source: ET Energy World, December 31, 2020)

Tesla to Enter India in 2021: Mr. Gadkari

Union Minister Mr. Nitin Gadkari has said on 27th December 2020 that American electric car major Tesla is set to start its operations in India in 2021 and would also look at setting up of a manufacturing unit based on demand. The Road, Transport and Highways minister has been pushing for green fuel and electric vehicles for cutting India's huge Rs 8 lakh crore crude imports. Tesla Inc. co-founder and chief executive Elon Musk had in October said the company will enter the Indian market in 2021.

(Source: PTI, December 29, 2020)

Wind Energy Powers More Than Half of UK Electricity for First Time

Wind power accounted for more than half (50.67%) of Britain's daily generated electricity on 25th December 2020 in the wake of Storm Bella, according to energy giant Drax. The encouraging news comes ahead of COP26, the UN's global climate change summit, which will be held in Glasgow in 2021. The British government wants offshore wind farms to provide one third of the country's electricity by 2030, as part of its strategy to reach net zero carbon emissions by 2050 to help meet its commitments under the Paris climate accord.

Source: AFP, December 30, 2020

Discoms' Dues to Power Generation Companies Rise to Rs. 1.41 Trillion

Power producers' total dues owed by the distribution firms rose over 35% to Rs. 1,41,621 crore in November 2020, reflecting stress in the sector. The distribution companies (discoms) owed a total of Rs. 1,04,426 crore to power generation firms in November 2019, according to portal PRAAPTI (Payment Ratification And Analysis in Power procurement for bringing Transparency in Invoicing of generators). In November 2020, the total overdue amount, which was not cleared even after 45 days of grace period offered by generators, stood at Rs. 1,29,868 crore as against Rs. 93,215 crore in the year-ago period.

(Source: Mint, 03 Jan 2021)

Regulatory Update on Wind Power

Waiver of Inter-State Transmission Charges and Losses on Transmission of Electricity Generated from Solar and Wind Sources of Energy

Ministry of Power, Government of India has issued an order No. 23/12/2016-R&R dated 15th January 2021 on the above subject. The gist of the order is given below:

Pursuant to the provisions of the Tariff Policy, Government have issued revised orders on the 5th of August 2020 providing that the inter-state transmission charges and losses will not be levied on the transmission of electricity generated from power plants using solar and wind sources of energy including solar-wind hybrid power plant with or without storage which have been commissioned on or before the 30th June 2023; provided that the sale of power is to entities having Renewable Purchase Obligations, irrespective of whether the power is within RPO or not – and provided that in case of distribution licensees, the power has been procured competitively in accordance with the guidelines issued by the Central Government.

It has been brought to the notice of the Central Government that there may be renewable power projects which are eligible for waiver of inter-state transmission charges and losses and having their scheduled commissioning date on or before the 30th June 2023 which are granted extension of the scheduled commissioning date by the Solar Energy Corporation of India/NTPC Limited or other Project Implementing Agencies on behalf of Government of India for reasons of Force Majeure or delays on the part of the transmission provider or inaction / delays on the part of Government Agency; and it had been represented that in such cases the eligible renewable power projects should not be deprived of the waiver of inter-state transmission charges and losses. It was also considered that provisions related to applicability of ISTS charges and losses waiver to all obligated entities needs a relook.

Government have examined this issue and have decided that there is merit in the contention. Government of India have therefore decided that in supersession of Ministry of Power's earlier order No 23/12/2016-R&R dated 13.2.2018, Order No. 23/12/2016-R&R dated 6th November, 2019 and 5th August 2020 no inter-state transmission charges will be levied on transmission of the electricity generated from following power plants for a period of 25 years from the date of commissioning of the power plants which meet the following criteria:

Power plants using solar and wind sources of energy, including solar-wind hybrid power plants with or without storage commissioned upto 30th June, 2023 for sale to distribution licensees, irrespective of whether this power is within RPO or not, provided that the power has been procured competitively under the guidelines issued by the Central Government. Power from such solar and wind plants may also be used for charging of storage including Hydro pumped storage plants:

Provided that where any renewable power project which is eligible for waiver of inter-state transmission charges and is having its scheduled date of commissioning on or before 30th June 2023 is granted extension of time from the commissioning on account of Force Majeure or for delay on the part of the transmission provider in providing the transmission even after having taken the requisite steps in time; or on account of delays on the part of any Government Agency, and the power plant is commissioned before the extended date; it will get benefit of waiver of inter-state transmission charges on the transmission of electricity generated by the power plant as if the said plant had been commissioned on or before 30th June 2023:

Provided also that where a Renewable Energy generation capacity which is eligible for ISTS waiver in terms of the extant orders, is granted extension in COD by the competent authority, the commencement and the period of the LTA shall also get extended accordingly,and it will be deemed that the period of ISTS waiver is extended by the said period.

Relaxations for Renewable Energy Projects

Ministry of New and Renewable Energy, Government of India vide letter No. 283/114/2018-GRID Solar 22nd December 2020 has requested SECI/NTPC/ NHPC/States/UTs to consider below three relaxations for all RE projects: (These instructions were issued by Ministry of Finance, Government of India, Department of Expenditure, Procurement Policy Division vide letter No. F.9/4/2020-PPD Dated the 12th November 2O2O.)

i. Reduction of Performance Security from existing 5-10% to 3% of the value of the contract.

ii. No provisions regarding Bid Security should be kept in the Bid Documents in future and only provision for Bid Security Declaration should be kept in the Bid Documents.

iii. No Provision to be kept in the Bid Documents regarding Additional Security Deposit/Bank Guarantee (BG) in case of Abnormally Low Bids.

Compiled by **Rishabh Dhyani**, Kshema Power

Snippets

Government Plans Tenders for Storage to Smoothen Clean Energy Supply

In an attempt to address the intermittent problem of wind and solar power, the Ministry of New and Renewable Energy (MNRE) is working on issuing tenders for pure storage capacity, said Mr. J.N. Swain, Managing Director of the Solar Energy Corporation of India, the nodal agency through which MNRE conducts auctions. "This (intermittent power) is one of the major concerns brought up by grid operators, power companies and utilities. With solar, we have already issued the round-the-clock and the peak power tender," he said. He spoke about the need for industrial decarbonation through renewable power. "Renewable energy with storage can serve as a better solution for replacement of diesel based generation which medium and small scale industries are currently using as power back-ups. This would be a game changer; a lot of the emission issues from the industry can be tackled," he said.

Source: ET Bureau, November 28, 2020

India Only Major Country Set to Achieve Targets of Paris Agreement: PM Modi

India is the only major country which is moving in the right direction to achieve the targets of the Paris Agreement, said Prime Minister Mr. Narendra Modi on 24th December 2020 while adding that India is leading the world in environmental protection through international solar alliance.

Source: ANI, December 24, 2020

First-Ever Service Rules Make Discoms Liable to Pay up to Rs. 1 Lakh Compensation for Outage

Distribution companies (discoms) will be liable to pay compensation of up to Rs. 1 lakh for resorting to wanton blackouts and will have to deliver other services such as installing a new connection, replacing or shifting a meter and changing the load within stringent timelines under first-ever service rules and consumer rights for the power sector announced by the Centre.

Source: TNN, December 22, 2020

India Sought After for Green Energy Pacts, Says MNRE Secretary

Foreign countries are actively seeking partnerships in renewable energy with India, whose ambitious targets will translate into an investment opportunity of Rs 1 lakh crore per year over the next decade, renewable energy secretary Mr. Indu Shekhar Chaturvedi told ET.

"Bilaterally, we see great interest abroad in the Indian renewable energy story. Countries with impressive renewable energy capacities and experience are keen to partner with India," he said. Officials said that India is the world's fastest-growing market for renewable energy, offering huge investment opportunities, as the country has set ambitious targets to expand capacity. India is already among the world's top renewable energy producers with investments of more than Rs 4.7 lakh crore in six years.

Source: ET Bureau, November 26, 2020

5G Connected Smart Substations to be Trialled by UK Power Networks

UK network operator UK Power Networks has been given the go ahead for a world first pilot of 5G connected smart substation operation. Project Constellation is aimed to develop a decentralised intelligence and control system at the substation level, with the substations communicating directly with each other via 5G. This arrangement is in contrast to the centralised control and communication systems currently used by the network operators. The goal is to optimise utilisation of the substations in order to free up capacity and thereby support the growth in renewable energy generation. The project, one of five approved in the latest round of regulator Ofgem's Network Innovation Competition, has been awarded up to £14.4 million.

Source: Smart Energy, 7 December 2020

First 14-MW Off-Shore Turbine

GE Renewables has announced a new 14-MW version of its Haliade-X wind turbine which will be planted at the world's largest off-shore wind farm Dogger Bank. The Haliade-X was introduced a couple of years ago as a 12-MW turbine capable of producing 45 percent more energy than any other offshore wind turbine on the market. The Haliade-X stretches to an incredible 260 meters in height with each of its three blades measuring 107 m making them the longest off-shore blades ever made. GE Renewable Energy has now announced that an upscaled 14-MW version of the turbine will follow, and will feature as part of phase C of the Dogger Bank project.

Source: New Atlas, December 22, 2020

NGT Directs Centre, States to Install 'Bird Diverters' on Existing Solar and Wind Powerlines

The National Green Tribunal (NGT) has directed the Centre through the Ministry of Environment Forests and Climate Change (MoEFCC) and other states on 23rd December 2020 to install 'Bird Diverters' on existing solar and wind powerlines as soon as possible and preferably within four months. NGT issued several directions while disposing of a petition on an NGO, Centre for Wildlife and Environmental Litigation through Bhanu Bansal who stated that there is an urgent need to protect and conserve the great Indian bustard as the same is on the verge of extinction. Tribunal further directs the respondents to provide fresh permission only after ensuring the underground powerlines in new projects. It has also directed the MoEFCC to take appropriate steps to ensure that EIA includes Impact on Biological Diversity for such kinds of Solar Energy Projects.

Source: ANI, December 24, 2020

Snippets

KEY BUDGET ANNOUNCEMENTS - UNION BUDGET FY 2021-22

Power & Renewable Energy

1. **Setting up of DFI:** India will set up a new development finance institution (DFI) called the National Bank for Financing Infrastructure and Development. The institution will be set up on a capital base of Rs 20,000 crore and will have a lending target of Rs 5 lakh crore.
2. **Higher Capital Allocation:** Higher allocation of Rs 1000 crore to SECI and of Rs 1500 crore to IREDA.
3. **Viability of Discoms:** The fund allocation of Rs 3.05 lakh crore over five years will focus on upgrading the infrastructure and technology of the ailing power distribution companies (Discoms) to make them more efficient and reduce their widening financial losses. The package will focus on measures like separating power feeder grids for farmers and residential users, and installation of prepaid smart meters.
4. **Monetisation of Transmission Assets:** A National Monetisation Pipeline of potential brownfield infrastructure projects to be launched and power transmission assets of Rs 7,000 crore would be transferred to Power Grid Infrastructure Investment Trust (InvIT).
5. **Competition in Electricity Supply:** Framework will be put in place for the consumer to choose their electricity Supplier from more than one Discom.
6. **Hydrogen Energy Mission:** Government proposes to launch hydrogen energy mission in 2021-22 for generating hydrogen from green power sources.
7. **Custom Duty:** Custom Duty increased from 5% to 20% for Solar Invertors. Custom Duty increased from 5% to 15% for Solar Lanterns.
8. **Phased Manufacturing Plan:** Phased manufacturing plan to be introduced for solar cells and panels.
9. **PLI Scheme for Battery Manufacturing:** Production-linked incentive scheme has been announced for 13 sectors which includes battery manufacturing.

PM Mr. Modi Lays Foundations for Renewable Energy Megapark in Kutch

Prime Minister Mr. Narendra Modi laid the foundations for world's largest renewable energy park on 15th December 2020, set to produce a massive 30 GW of electricity. The vast project in the Kutch region of western Gujarat state is spread over an area of 72,600 hectares (180,000 acres), the size of Singapore, will contain solar panels, solar energy storage units and windmills. The hybrid renewable energy park will be largest in the world. Mr. Modi, also said that it would also help the world's second-most populous country reduce its carbon dioxide emissions by up to 50 million tonnes per year.

Source: AFP, Dec 15, 2020

SJVN signs MoU with IREDA for Green Energy Projects

The Shimla-based Satluj Jal Vidyut Nigam (SJVN) Limited has entered into a MoU with the Indian Renewable Energy Development Agency Ltd (IREDA). The IREDA will provide its services to the SJVN for green energy projects. The MoU was signed by Mr. Nand Lal Sharma, CMD, SJVN and Pradip Kumar Das, CMD, IREDA on 7th Dec. 2020 by virtual mode. As per MoU, IREDA will undertake techno-financial due diligence of renewable energy, energy efficiency and conservation Projects for SJVN. Under the MoU, IREDA will also assist SJVN in developing an action plan to create and acquire renewable energy projects for next 5 years.

Source: Statesman News Service, December 8, 2020

Wind Energy Companies Still Waiting for Dues from State Discoms

Wind power developers worry that they have been singled out by state distribution companies, as delays in payments stretch to over a year in several instances and could force them to default on their loans. During the same period, the same states have commissioned various new solar energy projects.

Source: Energy Infra Post, 9th January 2021

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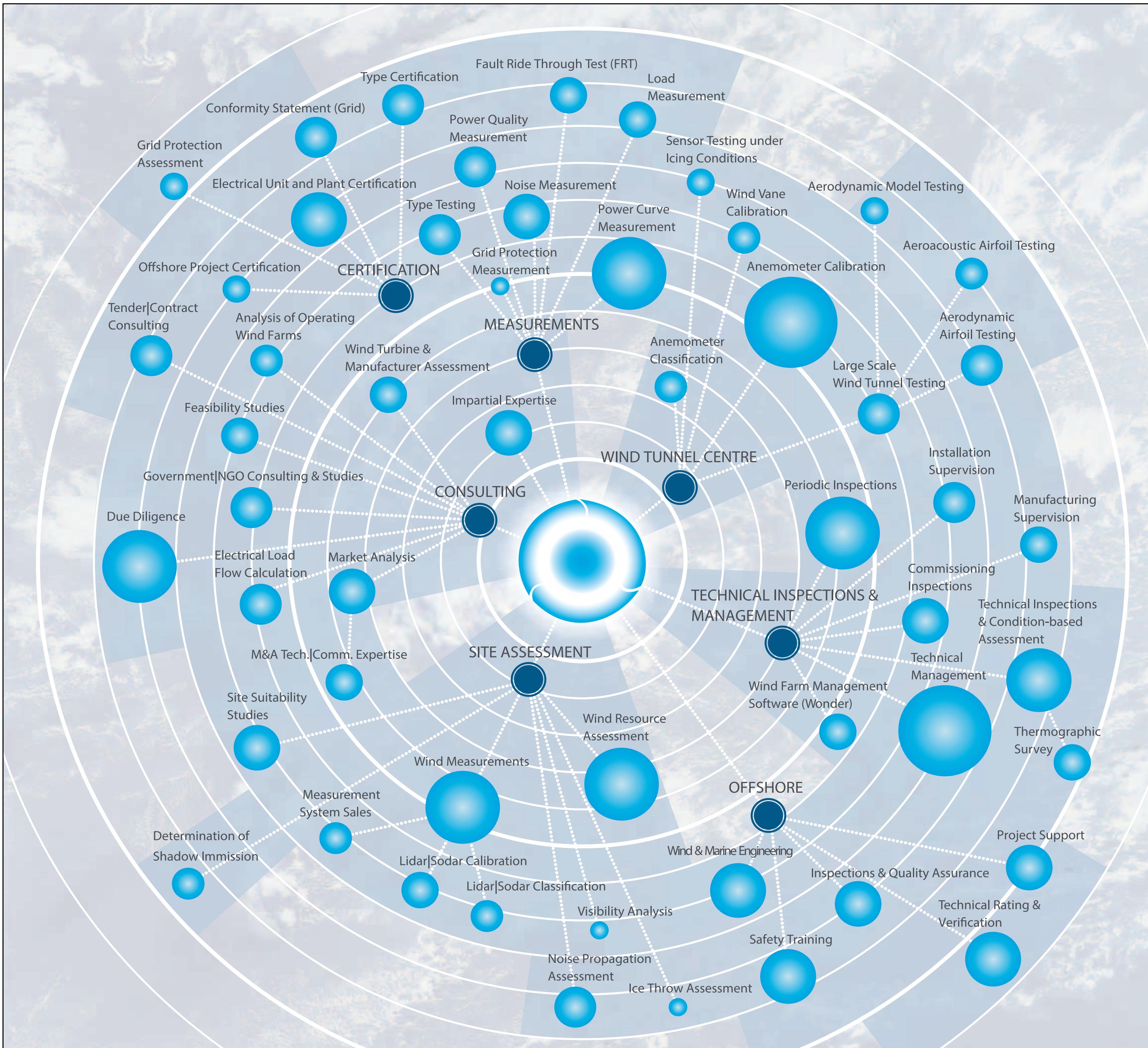

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