Indian Wind Power

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An Autonomous Research & Development Institution under the Ministry of New and Renewable Energy, Government of India

Velachery - Tambaram Main Road, Pallikaranai, Chennai - 600 100

Phone : +91-44-2246 3982 / 83 / 84 Fax : +91-44-2246 3980 E-mail : info.niwe@nic.in Website : http://niwe.res.in

IWTMA
INDIAN WIND TURBINE MANUFACTURERS ASSOCIATION

Indian Wind Power

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Indian Wind Turbine Manufacturers Association

4th Floor, Samson Tower, 403 L, Pantheon Road, Egmore
Chennai - 600 008.
Email : secretarygeneral@indianwindpower.com
associatedirector@indianwindpower.com
Website : www.indianwindpower.com

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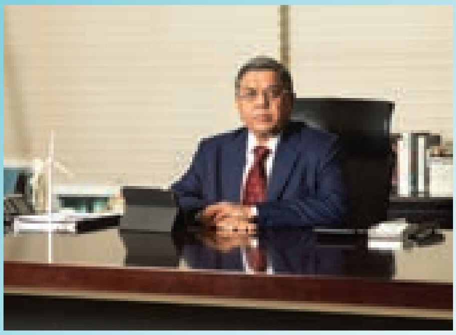


From the Desk of the Chairman – IWTMA

Dear Readers,

Greetings from IWTMA!

The Delhi Government is planning to reintroduce "the odd - even scheme" for car usage in November '19 to combat pollution, which aggravates in winters, due to burning of farm stubbles in the neighboring states of Punjab and Haryana. Whether it is a wise decision or not, climate change and pollution is on everyone's lips; but are we really doing anything to meet the challenge? In our April-May '19, issue, we carried news of 16-year-old Climate Activist, Greta Thunberg, who was leading a protest in Delhi. She is in news again to knock the door of none other than the President of the United States on the ill effects of climate change and global warming. We applaud the Government led by Hon'ble Prime Minister Shri Narendra Modi on banning plastics and more so on 'single use plastics' and waste created by such use. At the recently held United Nations Climate Action Summit in New York, the Hon'ble Prime Minister of India also committed to double India's renewable energy target to 450 gigawatt (GW) by 2030. This demonstrates India's unwavering resolve to mitigate climate change risks. These are great visionary approaches.

Government has set a target for onshore wind and solar energy, a programme for electrical vehicles and an ambitious programme for off-shore wind energy. But, in spite of the ambitious targets, Financial Year 2019-20 (FY20), is not measuring up to fulfill the 60 GW of wind energy target to be achieved by 2022.

Wind industry has time and again demonstrated to produce state-of-the-art wind turbines at perhaps, one of the lowest costs in the world with 80% localization, encompassing 4,000 vendors in the supply chain and creating direct and indirect employment in both urban and the rural sector. In comparison to solar, the wind industry, uses less water and land to produce energy. It offers a solution of energy security with affordable power to all on round the clock basis. The solution may lie in connecting the dots on land allotment, viable tariff below Average Power Purchase Cost (APPC) and link power connectivity to Wind Resource Assessment (WRA) areas. Needless to add the environmental benefits are far out reaching.

Though power is a concurrent subject and we have to promote renewable energy as a national programme cutting across the boundaries, and contribute to reduce the carbon foot print and save the planet for future generations.

On behalf of IWTMA, I wish our readers a **Happy Dussehra** and Diwali. Celebrate a smoke-free festival of lights.

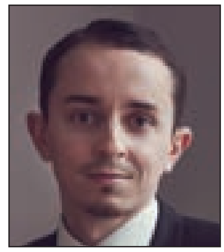
Happy Reading

With regards,

Tulsi Tanti

Chairman

Transformer - based Fault Ride through Test System with less Grid Burdens



Dipl. - Ing. Damian Slowinski
Head of Electrical Testing Lab
WindGuard Certification Varel, Germany
damian.slowinski@windguard.de

Dr. Kumaravel Rathinavel
Managing Director
Deutsche WindGuard India, Chennai, India
r.kumaravel@windguard.com

Introduction

Technically, this all new Fault Ride Through (FRT) test system switches from a series impedance to an auto-transformer at the moment of fault simulation. By using the transformer effect, the network load is considerably lower for most numbers of test cases compared to conventional test equipment. For example, in the event of a 50% drop, the ½ short-circuit current at the same longitudinal impedance can be expected compared to a conventional voltage divider. In addition to, Low Voltage Ride Through (LVRT) also High Voltage Ride Through (HVRT) can be simulated. Because of not using capacitors the usual problem with resonance points is not envisaged. The wave form of the voltage is much more consistent. This test system is also suitable for simulating not only pure amplitude changes but also vector jumps of the voltages. In nutshell, this system becomes simple and superior than the impedance based FRT test systems.

Description of Transformer, based FRT System

The test system is designed for networks up to 30 kV and rated currents up to 630 A. This results in possible Devices Under Test (DUT) up to 27 MVA rated apparent power. Due to a very small number of components, a single ISO container is sufficient to store all electrical components together.

The main circuit diagram is similar to a conventional voltage divider. Two event switches are carrying out as well double dips. A bypass assembly allowed changing the transformer configuration while keeping the DUT in operation.

Three multi pole coils working as an auto-transformer can be connected in different ways to generate LVRT or HVRT events.

Gas isolated switch gears are used for controlling the main circuit. They are compact and resistant against dirt. A protection relay is able to stop the switching sequence in case of any unexpected voltage or current behavior at grid or DUT side of the container.

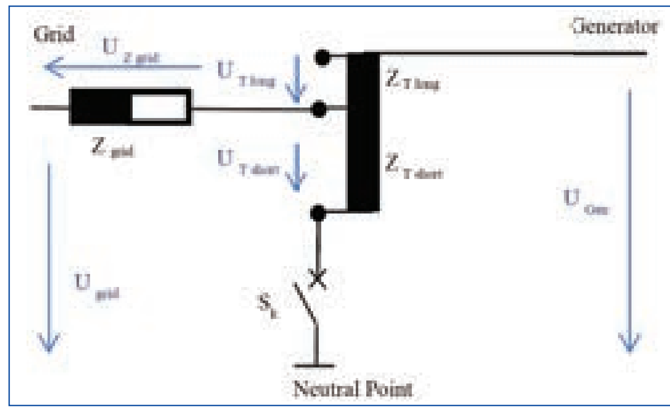


Figure 1: HVRT Operation Schematic

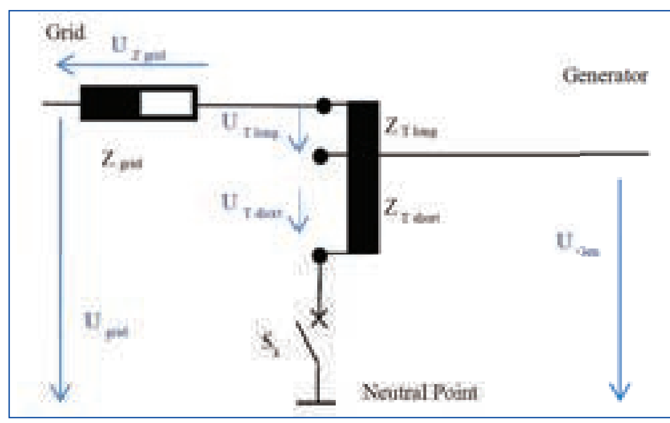


Figure 2: LVRT Operation Schematic

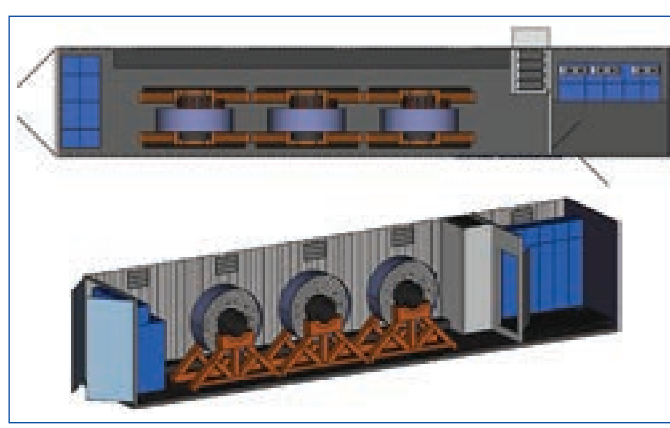


Figure 3: FRT Container Inner Arrangement

Figure 4: FRT Container of Deutsche WindGuard

Meetings the Requirements from Grid Codes

According to the continuously upgrading grid codes in Europe and in India, not only LVRT tests are necessary, also HVRT tests are becoming necessary.

The configuration to simulate short-duration voltage variations is based on the three transformers. It differs from conventional "Low Voltage Ride Trough" (LVRT) or "Under Voltage Ride Trough" (UVRT) test installations, which are based on the principle of a voltage divider.

In addition to under voltages, the configuration with the transformers allows the generation of over voltages, namely "High-Voltage-Ride-Through" (HVRT) or "Over-Voltage-Ride-Through" (OVRT).

In contrast to a standard voltage divider the voltage generated during the fault simulation results not from the impedances but it results from the number of windings of the autotransformer that had been configured by connections.

In comparison with a voltage divider a 50% voltage dip has the same longitudinal impedance also at the autotransformer setups. A voltage divider setup needs in the short circuit phase the same impedance as in longitudinal direction. The autotransformer needs the same number of windings to get the 50% voltage drop. Out of the square relation between the windings of the autotransformer, the overall impedance from the view of the grid is the double at the autotransformer compared to the voltage divider. Therefore, the short circuit current is the half. When voltage drops to zero residual voltage only longitudinal impedance is needed, which effects the same behaviors of both test set-up. But at all other tests the grid demand is less at the autotransformer.

The inside windings of the transformer have a lower impedance due to their smaller radius and are to be used for the longitudinal impedance. The outside transformer windings are thus to be used for the event path.

The coil is divided in a lot of steps over the overall range. Therefore, a high number of different configurations are possible. The overall impedance between step 0% up to step 100% is expected high enough to perform tests also at weak grids. At stiff grids only a part of the coil needs to be used. Double events are to be treated in the same manner. To achieve an optimal utilization of the transformer, temperature sensors can be installed. The power balance between the transformer input and output is calculated in the measurement equipment.

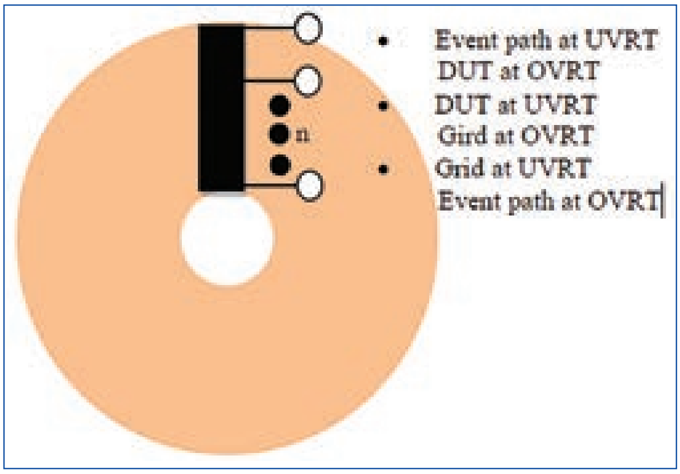


Figure 5: Symbolic Autotransformer with n Numbers of Connectors to the Windings

Summary

Depending on the mains conditions, voltages of up to 130% of the input voltage can be achieved by the transformer. Initial measurements have already been carried out on the medium-voltage grid. These show that the basic assumptions are correct. Out of not using capacitors there are no problems with resonances with the grid during HVRT tests as it can be observed by capacitor inductance assemblies. Due to the cost-effective design with the enormously increased application possibilities, a quick replacement of conventional voltage dividers is expected. Deutsche WindGuard has so far produced three numbers of such transformer based FRT containers.

Snippets on Wind Power

Tuticorin VOC Port Aims to Generate 10 MW Green Energy

V O Chidambaranar Port Trust is working on projects that would facilitate generation of 10 Mega Watt power in an eco-friendly manner, said T K Ramachandran, chairman of V O Chidambaranar Port Trust while addressing the port stakeholders at the Independence Day celebration at the Port School ground on 15th August 2019. He said that the eco-friendly initiatives include a five MW solar power plant at Rs 25 crore and they are also preparing the detailed project report for five MW wind energy generation in the port's land.

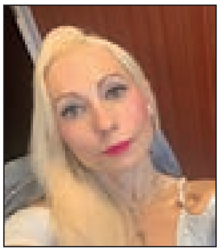
Source: TNN, Aug 16, 2019


LM OFFSHORE

Historical Perspective of Wind Turbine Development from Past to Present

Dr. Raj Shah
Director, Koehler Instrument Company, New York
rshah@koehlerinstrument.com

Dr. Harpal Singh
Research Scientist, Tribology & Materials, Sentient Science, Indiana
hsingh@sentientscience.com



Ms. Shana Braff
Social Media Specialist
Koehler Instrument Company, New York

Harkening back to ancient times, and spanning through to the present day, a wide cross section of the world's populace has found innovative ways to wield the natural power of one of our most abundantly-available renewable resources: the wind. It was the evocative element's immutable force which led, with its silent siren's song, history's iconic lovers, Antony and Cleopatra, by gilded barge, down the mythical Nile River in 42 BCE, as it had been transporting sea-faring travelers since at least as far back as 5000 BCE. The Egyptian Goddess Isis is known as the "Goddess of 10,000 Names", one of them being the "living north wind". This ethereal entity, wind, was harnessed by many early civilizations. Embryonic incarnations of windmills were pumping water in China as early as 200 BCE. Concurrently, vertical-axis windmills replete with woven reed sails were busy grinding grain in Persia and the Middle East. The element of air, synonymous with wind, was inexorably linked to spirit for these nature-based societies. Although the wind is invisible, it is visceral and all-encompassing, and humanity seems to have an innate calling to be both literally and figuratively moved by its presence. Analogous to the air we breathe, both utilitarian in function, and imbued with the esoteric, the wind vivifies everything it encounters and billows to us all to join in its cosmic dance.

The might of this meteorological phenomenon has captivated man for thousands of years. Ancient Greek mythology personified its human-like pantheon as the masterminds behind the mercurial patterns of weather which remained an enigma to the pre-scientific world. Today, while we view the wind through a more practical, and yes, prosaic lens, we are no less enamored of, and dependent upon, its awesome propulsive possibilities.

The 11th Century saw people in the Middle East utilizing windmills extensively for food production. Returning merchants and crusaders, who were blown away by this idea, then carried news of it back to Europe. The Dutch, the people who are, perhaps, most closely identified with the larger-than-life image of the mighty windmill, further refined the device and perfected it for draining lakes and marshes in the Rhine River Delta. Subsequently, settlers took this technology to the New World in the late 19th Century. It was then that they began employing windmills to pump water for farms and ranches and later to generate electricity for powering homes and businesses.

Figure 1: Ancient windmill used for crushing grains

Figure 2: Dutch wind mills used for pumping water

Windmills were used by American colonists for grinding wheat and corn, to pump water and to cut wood at sawmills. The burgeoning rise of electric power found wind energy exploring new uses in lighting buildings remotely from centrally generated power. During the 20th Century, miniature wind plants, sized for farms and houses, as well as grander utility-scale wind farms, which could be synched up to electricity grids, were developed.

The premier turbine employed to transmute wind energy into power, as opposed to windmills, which are used to grind grain or pump water, was built by Professor James Blyth of Anderson's College, Glasgow (currently Strathclyde University) in 1887. Blyth tested a trio of various turbine designs which culminated in a 10-meter-high (33-foot-tall), cloth-sailed wind turbine. It was later erected in the garden of his vacation cottage located in Marykirk in Kincardineshire. It is purported to have been in use for a quarter of a century. This breathtaking breakthrough in the field of wind power, spearheaded by Blyth, heralded the nascence of wind turbine innovation. An American inventor closely followed in his well-trodden footsteps: When Charles Brush breezed in, the year was 1888. He came on the scene with his 12-kW turbine featuring 144 cedar blades, each boasting a rotating diameter of 17 meters.

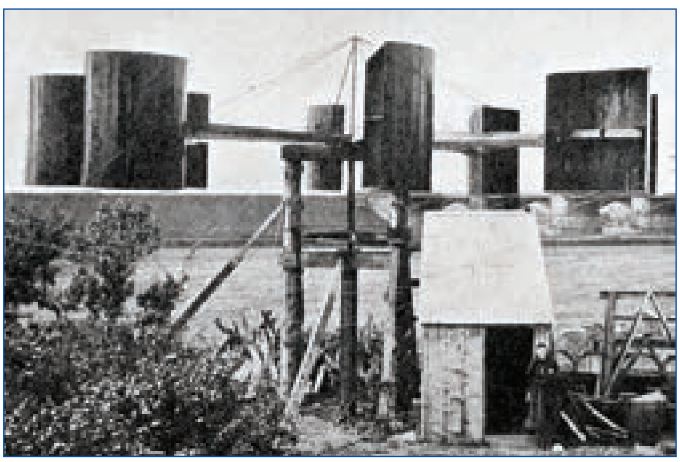


Figure 3: Vertical axis design of Blyth's windmill

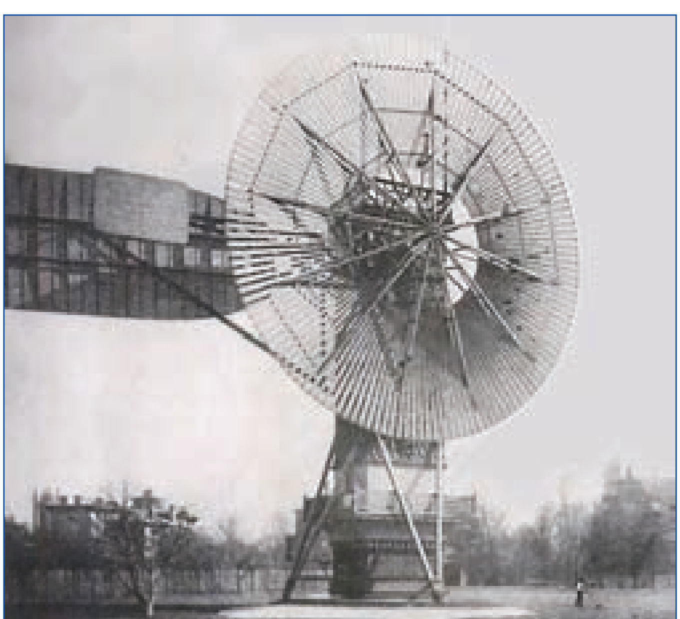


Figure 4: Horizontal axis design of Charles Brush's windmill in 1888 used for generating electricity (right) (24)

The next level in wind power modernization came from Danish scientist, Poul la Cour, in the 1890s, which resulted in approximately 2,500 turbines appearing in Denmark by the turn of the century, with a combined peak power capacity of 30 MW. In addition to power, the Dane's wind turbine blew everyone away by producing hydrogen in tandem with power.

Globally, wind-powered turbines were installed by the millions after the above mentioned achievement, most saliently in the American Midwest, in order to power irrigation pumps. The inchoate prototype of today's horizontal-axis wind generators, in 1931, was put into use at Yalta, in Russia. This was a 100-kW generator atop a 30-meter-tall tower, yielding a load factor of 32%. Finally, in 1941, the world's premier 1.25-MW turbine was put on the grid on Grandpa's Knob in Castleton, VT.

Subsequently, around the mid-1950s, the first modern wind turbine was built in Denmark. The Danish Wind Industry Association (DWIA) stated that the 200-kW Gedser wind turbine was constructed in 1956 by engineer Johannes Juul for electric company SEAS on the Gedser coast in southern Denmark. The concept consisted of a tri-bladed upwind turbine with electromechanical yawing, and asynchronous generator was an innovative design that served as a blueprint for modern wind turbines. However, it would certainly look a bit outdated in light of present day alterations. Stall-controlled, the turbine heralded the invention of emergency aerodynamic tip brakes. These were released by the centrifugal force as a failsafe in the event of overspeed. According to a statement by the SEAS organization, as cited on Powermag.com, "Basically, the same system is used today on modern stall-controlled turbines," it was further noted that Juul's revolutionary turbine ran for more than a decade, astonishingly, "without maintenance."

In the aftermath of the initial oil crisis, in 1973, wind power began to gain momentum as Denmark, Sweden and Germany, in addition to the UK and U.S., along with other countries, clamored to construct even more commodious contraptions. Danish developers, in 1979, were successful in erecting two 630-kW wind turbines: a pitch-controlled and a stall-controlled model.

The oil shortages of the 1970s revamped the energy landscape for the U.S. and the world at large. It also fueled a demand for alternative energy sources, opening the floodgates for the reemergence of the wind turbine to produce clean energy independent of the fossil fuel industry.

During the time period of 1974 through the mid-1980s, the U.S. government worked with the wind turbine industry to advance the technology and enable development and deployment of massive commercial wind turbines. Large-scale research wind turbines were developed under a program overseen by the National Aeronautics and Space Administration to create a utility-scale wind turbine industry in the United States. With funding

Figure 5: An example of upwind facing, horizontal axis, 3 blade modern day wind turbine

from the National Science Foundation, and later followed by monetary support from the U.S. Department of Energy, 13 experimental turbines were put into use utilizing four major wind turbine designs. This research and development program preceded several of the multi-megawatt turbine technologies active today. The monolithic wind turbines developed under the auspices of this program set several world records for diameter and power output.

Anemic oil prices threatened to render electricity from wind cost prohibitive in the 1980s and 1990s. However, thanks, in part, to federal and state tax incentives implemented in the 1980s wind energy managed to thrive in California. These incentives bankrolled the heavy use of wind power for utility electricity. Aggregated in large wind resource areas, these turbines, such as Altamont Pass, would be considered inconsequential and economically undesirable by current wind farm development protocols.

Although, wind energy's expansion in the U.S. halted exponentially after tax incentives were waived in the late 1980s, wind energy continued to flourish in Europe, buttressed partially by a revival of environmental concerns, in light of scientific studies that alluded to the potentially deleterious impact on the global climate if the use of fossil fuels continued to escalate without compunction.

Across the United States, wind power capacity has tripled over the past decade, due to plummeting costs, in addition to the technology becoming more robust, and compounded by the federal government's energy labs report according to Insideclimatenews.org. Land-based wind farm turbines are continuing to grow larger and more efficient states the Lawrence Berkeley Labs report noted on the aforementioned site. This has catapulted the average turbine capacity to 2.43 megawatts, which is an increase of 8 percent from the year prior and up more than 200 percent since the late 1990s.

Furthermore, for turbines installed in the U.S. from 2000–2018, average height of the turbine hub increased from 190 feet to 288 ft equivalent to the Statue of Liberty and rotor diameter increased from 160 ft to 380 ft. about the length of a soccer field. An offshore wind turbine is built by General Electric (GE) which has rotor diameter on the towers of the golden gate bridge and the surface area of the blade sweep is equivalent to seven American football fields. The power capacity of this design is rated at 12MW, significantly higher than 2018 average turbine capacity. Rotors are continuing to get bigger, blades longer and turbines steeper, with an increasing number of projects surpassing 500 feet. This is notable due to it being the level at which federal aviation regulators are required to issue a special permit. Elevation in size and other design improvements are allowing turbines to operate at levels approaching optimal capacity. Turbines built between 2014 and 2016 had an average "capacity factor" of 42 percent, in comparison to an average capacity factor of 31.5 percent for projects cultivated in the period from 2004 to 2011.

Wind power heralds back to antiquity, yet, as the wheel of time spins ahead, it still manages to be a thriving, growth-oriented and ever-evolving industry at the forefront of renewable energy achievements. Innovations in state-of-the-art lubricants and maintenance strategies are continuing to make tremendous strides toward unparalleled standards in gear and bearing lubrication, which will continue in an effort to breeze by the competition in the arena of alternative energy.

Note: This is the first article of a series of 3 articles, the second one is focused on lubrication and the last one is focused on asset management and mechanical issues and will be published in subsequent issues.

(Dr. R. Shah is an elected fellow of AIC, RSC, STLE, NLGI and EI. He is honored by the Engineering Council, Royal Society of Chemistry, Energy Institute, Science Council and the National Certification Commission in Chemistry and Chemical Engineering with the following designations: CPC, CCHE, CSci, CChem, CEng, CPEng.)

References

1. http://www.sjsu.edu/faculty/watkins/cleopatra.htm
2. https://www.petro-online.com/article/measurement-and-testing/14/koehler-instrument-company-inc/lubrication-of-wind-turbines-is-anything-but-a-breeze/2424
3. http://windenergyfoundation.org/about-wind-energy/history/
4. https://www.accuweather.com/en/features/trend/weather-and-ancient-religion-g/70378
5. http://www.skf.com/us/products/lubrication-solutions/lubrication-systems/lubrication-solutions-for-specific-markets/windenergy/index.html
6. https://www.machinerylubrication.com/Read/395/wind-turbine-lubrication
7. https://www.energy.gov/eere/wind/wind-energy-technologies-office
8. https://www.wind-energy-the-facts.org/
9. https://www.power-eng.com/articles/print/volume-117/issue-5/features/wind-turbine-lubrication-and-maintenance-protecting-investments-.html
10. https://www.windpowerengineering.com/operations-maintenance/lubricants/lubricants/
11. https://www.altenergymag.com/article/2016/07/maintenance-and-lubrication-of-wind-turbines/24074
12. https://isiopolis.com/2015/05/03/isis-of-the-winds/
13. https://www.conserve-energy-future.com/various-wind-energy-facts.php
14. https://www.conserve-energy-future.com/pros-and-cons-of-wind-energy.php
15. https://helpsavenature.com/wind-energy-pros-cons
16. http://www.windustry.org/pros_cons_wind_energy
17. https://www.kidsdiscover.com/teacherresources/whats-good-whats-bad-wind-energy/
18. https://www.theguardian.com/environment/2008/oct/17/wind-power-renewable-energy
19. https://www.helloinspire.com/blog/clean-power/who-discovered-wind-energy
20. https://telosnet.com/wind/early.html
21. https://www.powermag.com/changing-winds-the-evolving-wind-turbine/
22. https://www.vox.com/energy-and-environment/2018/3/8/17084158/wind-turbine-power-energy-blades
23. https://insideclimatenews.org/news/23082018/wind-energy-prices-market-growth-offshore-tax-credits-turbines-technology
24. https://en.wikipedia.org/wiki/History_of_wind_power

Snippets on Wind Power

Global Investment in Renewable Energy to Triple this Decade, says UN

Global investment in new capacity for renewable energy is on course to reach US$2.6 trillion by the end of this decade, more than triple the amount of the previous decade, a report commissioned by the UN Environment Programme says. The world's renewable capacity rose from 414 gigawatts in 2009 to 1650 gigawatts this year, and renewables now account for 12.9 per cent of all electricity generated on Earth. Energy from increasingly-competitive renewable sources such as wind and solar has quadrupled globally in just a decade but insatiable demand saw power sector emissions rise 10 per cent. This is more than triple the amount of the previous decade.

Source: Agencies, September 07, 2019

AP Government Decides Not to Reopen Existing PPAs

Andhra Pradesh Government has decided not to reopen the existing PPAs unless some irregularities were found in them. They would however examine the PPAs which have not yet been finalised. This decision has been taken by the State Government in view of financial crunch in the state Government informed centre in a letter.

Source: Hans News Service, 11 Sep 2019

Ignoring Clean Energy Transition Would Cost Hundreds of Billions of Dollars

Ignoring the need for a faster transition towards clean energy technologies would likely cost hundreds of billions of dollars, apart from the cost in terms of human suffering from run-away climate change, according to Mr. Jules Kortenhorst, the Chief Executive Officer (CEO) of US-based Rocky Mountain Institute. He added that the policy makers and business leaders must make investment decisions in line with an outlook for a rapid energy transition. The scenarios have not been quantified, and shares of wind and solar would grow over time and differ by country or region. But on the whole, under this scenario we would see a decarbonization of the bulk of the electricity systems of the world well before the middle of the century

Source: ET Energy World, September 12, 2019

Connected Windmills – Powered by Digital Twin

Prahallad C.R.
Business Architect - Digital Twin

Varun B.
Application Engineer - Digital Twin

Robert Bosch Engineering & Business Solutions PVT LTD, Bengaluru

One of the greatest challenges for the humanity in our current time is reducing the CO_2 emissions. As on date, there is an acute element of uncertainty that challenges the goals & objectives of Paris Climate Agreement. Inevitably, the world needs smarter, efficient, affordable and innovative solutions to pillar the efforts aimed at reducing the global CO_2 emissions. Undoubtedly, green energy has been a key contributor to this initiative and wind energy has seen an exponential growth in the last decade; driving green energy transition in a greater part of the world. Innovation in terms of digital transformation solutions can substantially accelerate this transition and one such solution that could help the windmill Original Equipment Manufacturers (OEMs), Independent Power Producers (IPPs) & critical component value chain players is Digital Twin.

What is Digital Twin?

It is a dynamic software model of a windmill or power generation process that relies on sensor & instrumentation data to understand its state, respond to changes, predict outcomes, improve operations & aid judgements for business decisions.

Figure 1: Cyber Physical System

In digital terms, it is a cyber physical system, which involves modeling windmills with all their geometrical data, kinematic functionality and logical behavior permitting the business operations to be simulated, controlled and improved. Its characteristics are as follows.

Evolving Digital Engineering Model – Built to address specific business problem

AI Powered Cyber Physical System – Built on basic principles of physics & engineering

Digital Prediction Machine – Generates physics, engineering & business insights

Augmented by Virtual Sensors – 3D immersive environment

Digital Collaboration for the C-Suite – Enables judgment based on data analytics

Modular Digital Transformation Solution – Defined & driven by IPPs & OEMs

Digital twins are becoming business imperative, covering the entire lifecycle of an asset/process and forming the foundation for Digital Transformation. Companies that fail to respond will be left behind.

Why Digital Twin for the Wind Power?

Today, windmills are designed, built & operated relying on diverse data sources, numerous operating environments & various business models. Engineers today work with enormous amounts of data; specialized teams create distributed operating models separately &

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With end-to-end business solutions Suzlon has led the green energy revolution to power India's social, economic and ecological development sustainably.
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conduct analysis to accomplish specific tasks. The most relevant current information & calculations computed by multiple teams may not be readily available at the same time, which is crucial for decision-making. This way of working in silos drives cost, inefficiencies & creates uncertainties representing underutilization of vast amount of time & resources. In order to enable engineers with that competitive edge in a tough business environment, companies must look intensely at innovations that will drive efficiency. This innovation is called Digital Twin.

Levelized Cost of Energy (LCOE) & Annual Energy Production (AEP) values orchestrate the maturity & degree of proliferation of wind energy. End of the day, policy makers & industry stakeholders pivot towards LCOE values that drives the supporting framework & corresponding energy targets. In this process, windmill OEMs will focus on improving user experience for their customers and machines, while IPPs would predominantly focus on reducing opex & increasing revenues with reference to their wind parks.

Basically, we are trying to solve here a mutually exclusive problem and the answer to this problem happens to be Digital Twin whose solution construct is based on sensors, software & services.

IPPs often encounter diverse challenges of various magnitude from day zero to the day when the windmill gets decommissioned, with every wind season posing different challenges. Many a times these problems cascade to the OEMs as well. Few of them are attributed to the following points.

Struggle to Manage – Distributed assets across various geographies or at difficult to access locations

Experiencing Unrest – Increasing uncertainties, untamed complexities & hazardous maintenance operations

Lacking Transparency – On O&M expenses, fleet OEE, MTBR, MTBF, RUL & TCO

Facing Invisible Inefficiency – No clarity on what causes what & no time tested solutions to fix problems

Spend on Repetitive Tasks – Struggling to shed off unplanned maintenance & adopt planned/need - based maintenance. Opex spend exceeds capex.

Building Digital Twin for the Windmill

Business Problem: A Digital Twin solution is always aimed at solving specific business problems and identification of these strategic problematic areas forms the foundation of twinning process. Few commonly seen problems are as follows.

- Remote asset interaction
- Elimination of unplanned downtime
- Minimization of planned downtime
- Reducing Cost of Energy
- Improving PLF & CUF etc.

The solution construct is majorly anchored on three aspects as shown below:

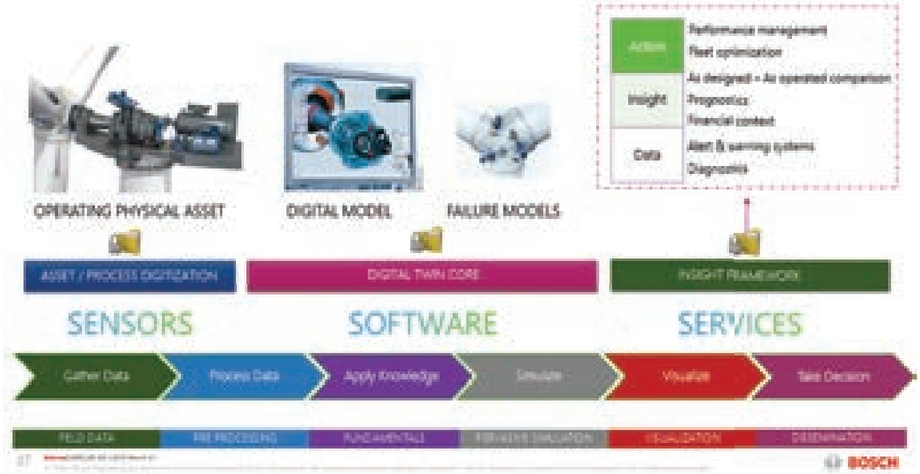


Figure 2: Three Aspects of the Solution Construct of a Business Problem

Building the Digital Twin Template

A functional twin's construct is based on pervasive engineering simulation. Its synchronized asset performance management mechanism constitutes for the windmill's dynamic simulation model forming the core of digital twin. In addition, a software construct to harvest information streams of digitally tracked windmills using instrumentation cluster, sensors, motion amplification & imaging caters to data analytics hub which generates engineering, physics & business insights. Pervasive engineering simulation augmented by Digital Twin & data analytics empowers the C-suite, engineering, operations & service organizations to explore & enhance design, product development, operation & maintenance using real-world conditions.

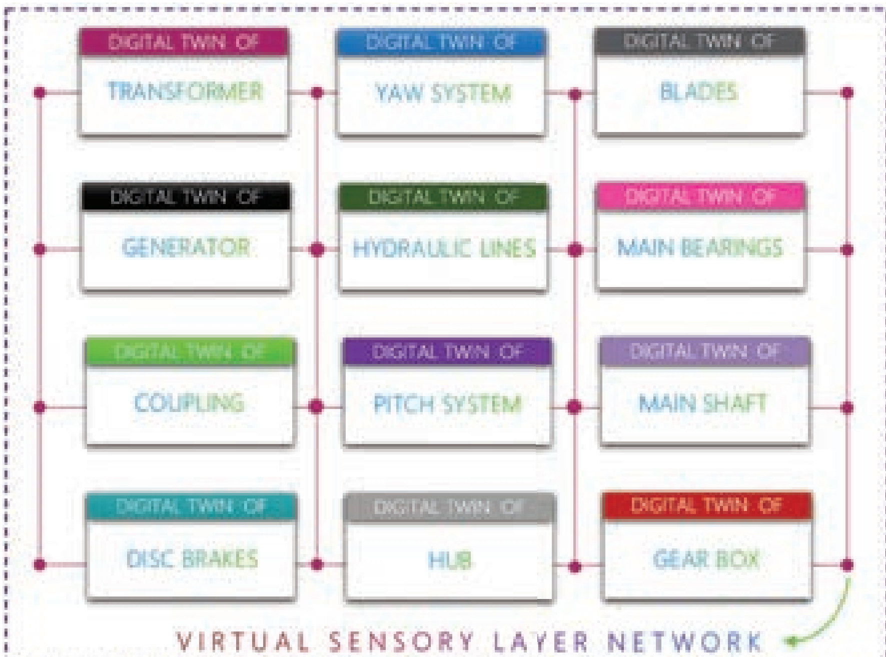


Figure 3: Virtual Sensory Layer Network

The state of all windmills could be modeled continuously, iteratively and pervasively by building prototypes & selectively extracting concepts that skew existing products or services while the operating field assets remain under operation in their core pervasive state. This is the IT & OT integration.

Creating the Digital Highway

A digital highway needs to be created for secure data transmission in order to circulate a single source of truth from the river of information.

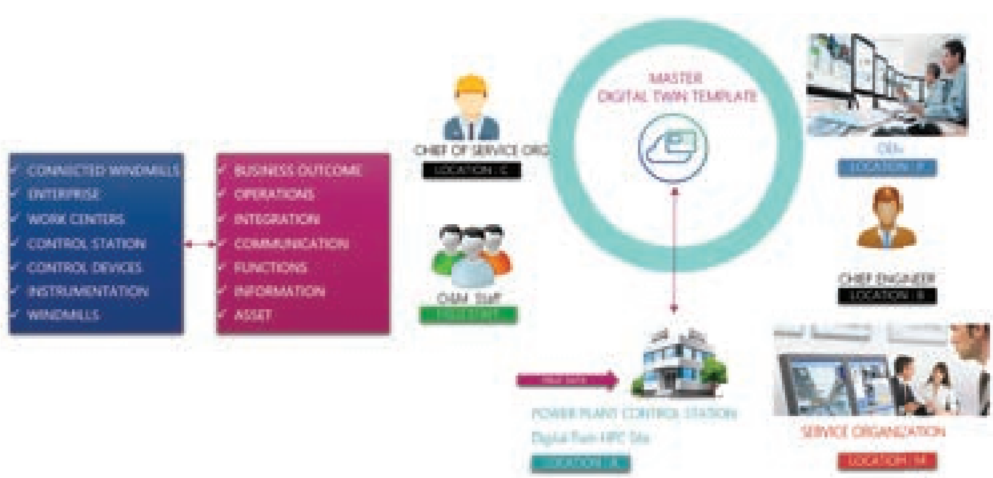


Figure 4: Creating the Digital Highway

Wind energy is data rich by default. This makes it an ideal use case for Digital Transformation. As wind energy goes mainstream, the future of wind power ecosystem would be defined by the digital ecosystem.

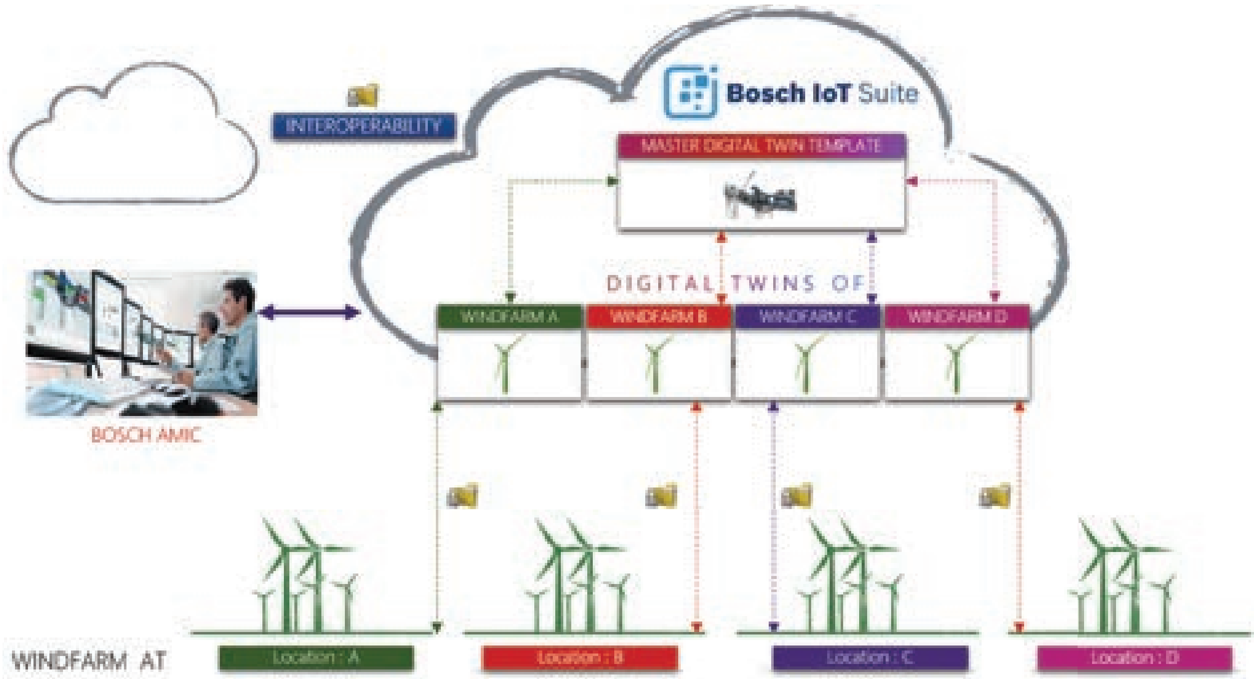


Figure 5: Digital Twin Deployment Method

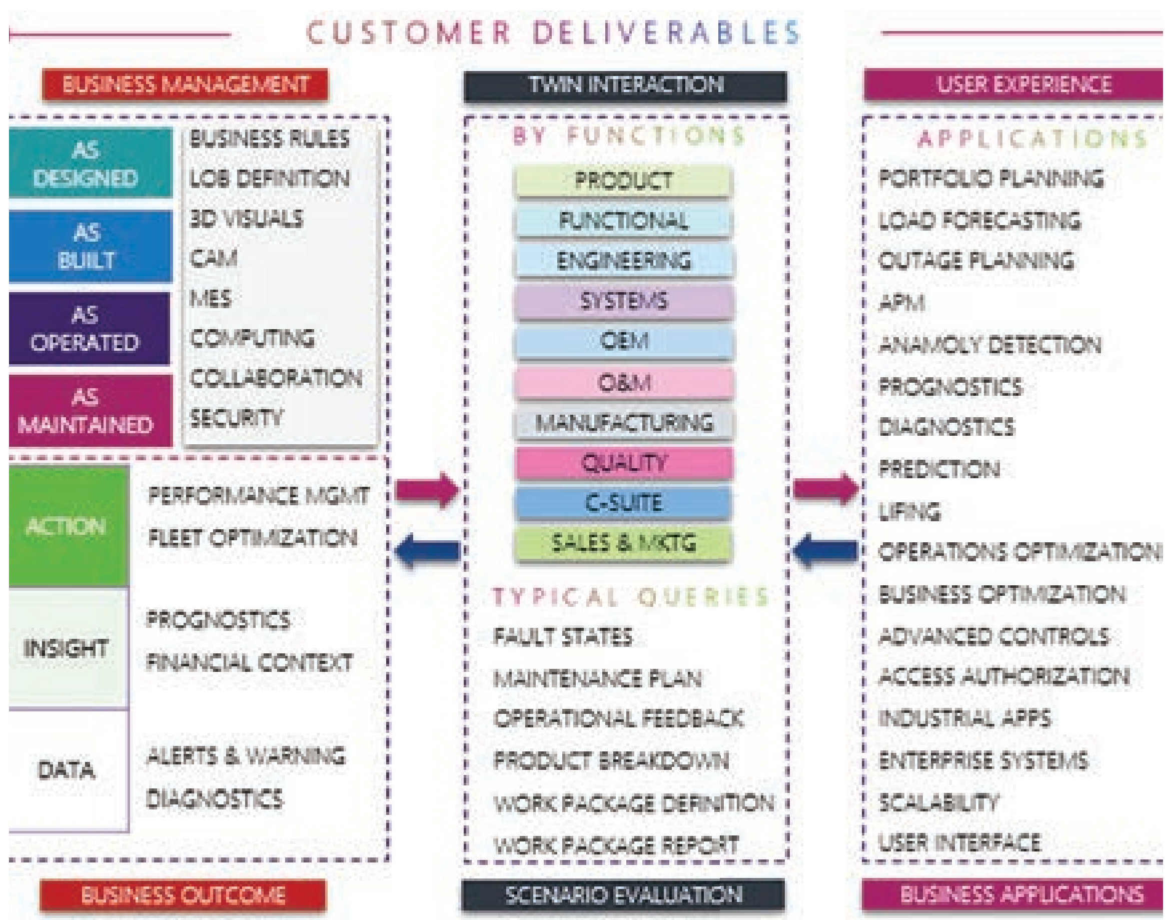
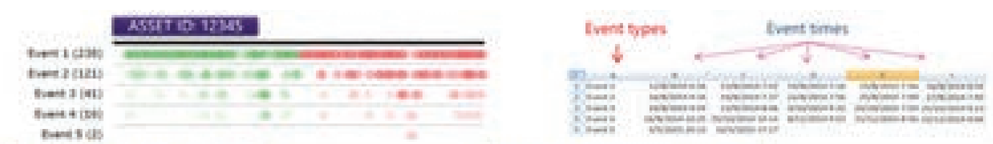


Figure 6: Typical Deliverables from Digital Twin

Figure 7: Visualizing the Digital Twin

Visualization Perspectives – Engineering Insights

- What factors can fail this asset? How could we mitigate failure? How much would that cost?
- What would be the consequence of this asset's failure on my business?
- What action should be initiated & what should be our overall strategy to optimize business objectives?



EVENT	SYMPTOMS OBSERVED BY TWIN	CONSEQUENCE	MITIGATION SUGGESTED BY TWIN	ASSOCIATED COST
1	IGBT gating inconsistency in the Power converter	CCF EVENT ID : 201902031348 Wind mill desynchronization possibility. Estimated revenue loss of X000 units	Replace IGBTs across the rectifier section Alert sent to Service Engineer ABC.	X000 USD$ Spare parts available at Store # 36
2	Eccentricity	CCF EVENT ID : 201902031355 Motor | SR # 23675 | Evolving dynamic eccentricity	OUT OF WARRANTY Replace drive end bearing or replace motor	Replacement part code : ABCDE Cost Y000 $. In-stock @ ware house No 4
3	Fatigue – Degree 2	CRITICAL EVENT ID : 201902031405 Can cause cracks on gearbox shaft	Customer notified – Immediate Machine stoppage recommended Alert sent to Service Engineer ABC & chief engineer.	Under warranty
4	Windings over hang experiencing electrical stress	CRITICAL EVENT ID : 201902031427 Might result in stator & rotor shorting	Customer notified – Immediate Machine stoppage recommended Alert sent to Service Engineer ABC & chief engineer.	Paid service to be proposed for the detailed inspection

Figure 8: Visualization Perspectives – Engineering Insights

Critical Elements to Build the Digital Twin

The challenge in the field to build a Digital Twin to drive targeted business outcomes rests entirely on the accuracy of the data across the spectrum of values, which bridges the physical & digital worlds at all points along the value chain. This opens the door to innovation & multiplies the possibilities that could be achieved through collaboration. IPPs & OEMs can now establish perpetual connectivity with the power parks, which eventually would help them to cut costs & derive new business models for additional revenue generation. To achieve a robust perpetual connectivity one needs to have in place the following points.

- Digital advisory to synthesize Digital Twin blue print
- Comprehensive asset Digitization models
- MBSE (High fidelity models)
- Model based & system based simulation
- Reliable telemetry
- Time tested IoT platform
- Scalable cloud solutions
- PLM integration
- Other enterprise applications

Bosch offers comprehensive digital solutions based on sensors, software & services.

Snippets on Wind Power

Renewable Energy Contracts Renegotiation will Jeopardize Investments: Pradhan

Speaking at Bloomberg New Energy Finance (BNEF) summit at New Delhi on 2nd August 2019, Oil and Steel Minister Sri Dharmendra Pradhan expressed concern over Andhra Pradhesh's decision to renegotiate existing renewable energy contracts with companies saying the move may jeopardize future investments in the sector. "Our Government has requested state governments to reconsider their decision, as this will jeopardize future investment in not only the concerned state but also the country as a whole," Pradhan said. Andhra Pradesh had last month announced its decision to renegotiate renewable energy contracts signed by green energy companies with the previous regime, drawing strong protests from developers. The Andhra Pradesh High Court last week issued a stay order on renegotiation of solar and wind pats, which is valid till August 22. Since then, the discoms of the state have been curtailing renewable power.

Source: ET Energy World, August 02, 2019

Jobs: Distributed Renewable Energy Sector to Create 400,000 Jobs in India

The distributed renewable energy sector is set to create 400,000 jobs in India by 2023, including 190,000 direct, formal jobs, almost double the current number, as well as 210,000 direct, informal jobs, according to the first annual jobs census measuring employment from decentralised renewables for rural electrification released today by industry body Power for All. The "Powering Jobs Census 2019: The Energy Access Workforce" aims to spotlight the energy skills and jobs needed to achieve Sustainable Development Goal (SDG) 7 – access to affordable, reliable, sustainable and modern energy for all. "Access to electricity means access to jobs. The powering Jobs census offers strong evidence of the important link between energy access and employment in countries where rural joblessness is at record highs," said Power for All Chief Research Officer and census lead researcher Rebekah Shirley.

To Discipline Discoms, Central Govt. Looking to Link Their Loans With Performance

Government is exploring a radical plan to help bring financial discipline to state electricity distribution companies (discoms) by limiting state governments' borrowing.

The move comes against the backdrop of a crisis at discoms due to their poor financial health, which has led to delayed payment to generation utilities. According to the broad contours of the plan, the Finance Ministry may withhold permission to the state to borrow to the extent of electricity losses not funded by the respective state governments.

"The idea is to make discoms' borrowing conditional to their performance," said a senior Union government official, requesting anonymity.

Source: www.livemint.com

Wind Industry Participation in Recent R&D Practices and Design and Development of Wind Turbines

K. Boopathi, Director and Division Head, Research & Development,
Resource Data Analytics & Forecasting and Solar Radiation Resource Assessment
National Institute of Wind Energy (NIWE), Chennai - 600 100, India

Introduction

National Institute of Wind Energy has conducted a brainstorming meeting on R&D and also Design and Development of Wind Turbines & Way Forward on 24th June 2019 at NIWE, Chennai. The discussions focussed on promoting research and development and role of NIWE and to develop practical strategies which would address design & development of Wind Turbine related issues, challenges, and potential solutions. Top research and development heads from wind turbine industry attended the meeting.

Need for the R&D and Design & Development of Wind Turbines

Various challenges such as components being outsourced and replications of it in the costing, capacity building facilitation were talked about. A line of comparison between the solar and wind energy sector was also cited and that the wind sector even after establishment of the turbine requires skilled manpower hence creating a social impact and economic outcome.

There is a gap between the academic and the industry sector and the need and the ways to bridge the gap between the two sectors in-order to create more effective and fruitful research and development in the domain of wind energy was put on the table for discussions. The Director General, National Institute of Wind Energy explained the need of academicians and industry experts in the research sector and requested everyone to present their inputs on how to go forward in this regard.

Formation of Committee

It was discussed that a committee may be formed within the wind industry and academic sector and a pool of experts can be created. The members of this committee shall be experts in respective domains. The talent pool committee members could identify and list out the thrust and research areas in their respective domains and facilitate a two-way communication.

The formation of the steering committee was also discussed. The committee members would have passionate experts from various domains in research and development area. The steering committee would address the thrust areas listed out by expert pool committee, define a clear framework which would include a clear objective, structure, and the outcome, decide if the project could be taken up as in-house R&D project by sharing the best practices to be adopted. The steering committee would put up the project proposal in front of RC council of NIWE in consultation with academicians in their expertise field. They would get opportunity to apply for MNRE/DST funding. In this way, the common issues could be streamlined through this channel and the academicians would get opportunity to take up these research areas for Master's and Ph.D. degrees.

Participation from World Experts

The participation of members from around the world in both the committee is welcomed. The Steering Committee will be formed to create a test facility for complete utilization of wind turbine setup, to include the skill set training and to validate & test the input & output meters.

The nominations of the committee members were to be sent to Shri. K. Boopathi. The meeting shall be conducted once in a quarter (September, December, March and June).

The importance of the meeting was recognized by all and was well appreciated as it had paved a direction for the future prospects in the research and innovation of the wind energy sector.

Coverage of Work

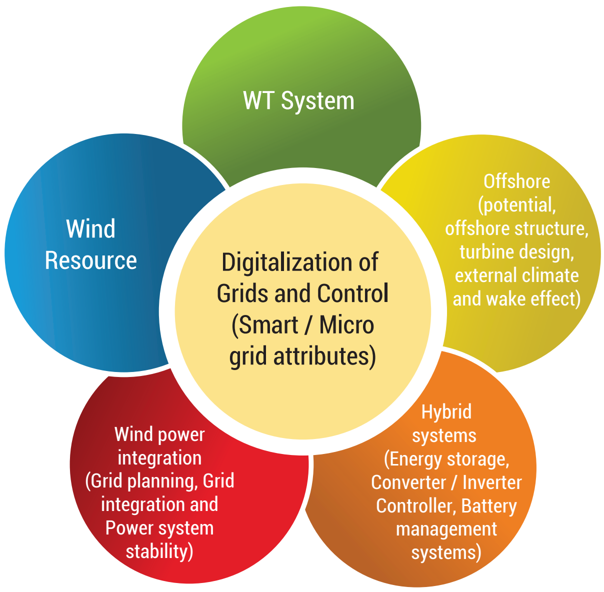
The deliberation was done on the following points.

1. Improve the performance and reliability of wind technologies
2. Key challenges: Design of Large WT and move to offshore
3. R&D Thrust areas
4. Shared design and development facility to address issues in
   - Design of Wind Turbine models for low wind regime (Class III Turbines)
   - Higher Hub height wind turbine towers with different design options for easy transportation (Hybrid material) hybrid geometry (lattice & tubular)

- Wind Turbine Model variants for hot climatic conditions
- New drive-train options

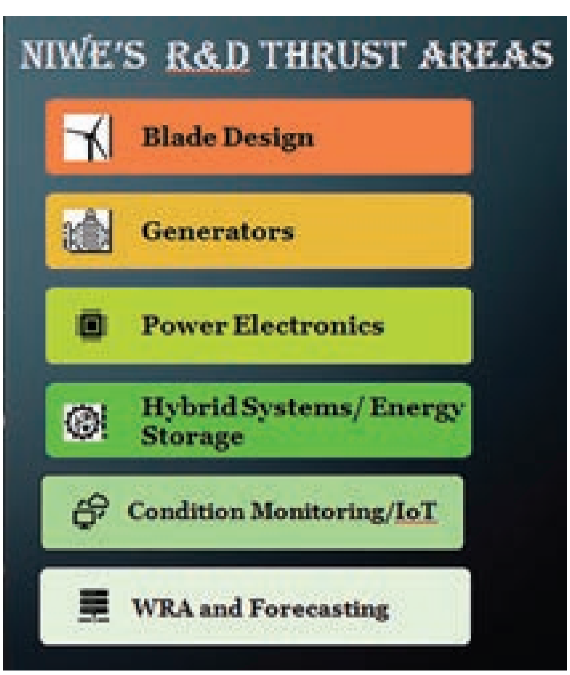
5. Design optimization & Standardization of sub-components: addressing the issues of ancillary industries coupled with performance, and engineering challenges
6. SWT that can be efficiently used in isolated locations
7. Interaction between OEM and Academia

Areas to Explore



Thrust Areas of NIWE Research and Development

NIWE has the following thrust areas for research and development. The detail of the research and development in each thrust area is given below.



A. Wind Resource Assessment

- Impact of turbulence
- Atmospheric complex flow modeling and experimentation
- Resource Forecasting tools
- Wind atlas
- Issues of spatial planning
- Micro sitting and array effects
- Mesoscale processes
- Climatic variability and historic trends

B. Wind Turbine Blades

- Structural analysis of composite blades
- Wind turbine aerodynamics
- Smart Rotor modeling
- Active blade elements
- Advanced Blade materials
- Novel rotor architectures
- Novel drive train designs and topologies

C. Generators & Grid Integration of Wind Turbines

- Impact of wind energy in Power systems
- Power Quality issues of RE with Grid integrity
- Steady state and Transient stability
- Grid codes and plant internal grid details
- Wind power forecasting

D. Condition Monitoring of Wind Turbines

- Wind turbines in diverse operating conditions
- Noise reduction
- Data acquisition, processing and quality assurance
- Data analysis and exploitation
- Advanced Electrical system design for high levels of penetration
- Energy & power management
- Recycling & Safe disposal of wind turbine components

E. Hybrid Systems

- Wind and Solar Integration
- Power converters and Inverter operations
- Energy storage, Battery and Battery management systems
- Energy management systems
- Automation and control

F. Ancillary Aspects of Wind R&D

- Testing and certification
- Manufacturing and supply chain
- Environmental impacts and sitting of wind projects
- Workforce development and education
- Operational data management
- O&M and diagnostics methods
- State of art methods and testing facilities of large scale wind turbines

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Electric Generators for Wind Turbines

Sasi K Kottayil
Professor, Amrita Vishwa Vidyapeetham, Coimbatore

The History

The Danes are the pioneers in world wind electricity generation. Professor Poul La Cour, the 'Danish Edison', began experimenting with it in his polytechnic of Askov and finally erected one as early as in 1891. Professor James Blyth of Anderson's College, Glasgow, had developed this technology earlier in 1887, but the Scottish did not take it to their fields unlike the Danes who improved it and shared the ownership across the generations.

Professor La Cour's generator was a stand-alone DC dynamo because AC was not very popular then. By 1910 several hundred units ranging in capacity from 5 to 25 kW were in operation in Denmark. While the Industrial Revolution replaced water pumping and grain grinding windmills by steam engines in the nineteenth century, the advent of fossil fuel based power generation censored the growth of wind electricity early in the twentieth century. But the long wartime blockade forced the Danes rely on wind for both mechanical and electric power. Electricity from the crude wind machines of an estimated total installed capacity of 3 MW was a valuable source of power to an impoverished rural Danish population during the First World War. When the situation changed after the war, the little wind power stations of Denmark eventually could not compete in upkeep or convenience with larger and more efficient steam turbo-generators. Yet, the Danes again returned to wind for electricity during the Second World War when there was acute oil shortage.

In 1924, USSR produced a 40 kW wind turbine generator (WTG) which used a synchronous machine. In another seven years they built and tested the world's first grid-connected WTG which reportedly worked well for 10 years. It was a 100 kW squirrel cage induction generator (SCIG) with a 30 m wind rotor rated at a wind speed of 11 m/s and connected to the grid through an 11 kV line. Being partially inspired by this Russian adventure and also being reportedly annoyed by his electricity bill, Palmer C. Putnam of United States started working on a larger wind electricity generator in 1934. The well-known Smith-Putnam machine, a product of university-industry collaboration, had a grid-connected synchronous generator of 1.25 MW capacity. It was erected at Grandpa's knob in Vermont in 1941. The machine generated power until a bearing failed and a blade fell off in 1943 and no replacement or repair was available due to war time priorities.

Figure 1: 1250 kW Smith-Putnam WTG

Interestingly, the Russian journey with the wind never took off. Almost a century later Russia's Putin says today that wind power is harmful to birds and earthworms will come out to disturb humans when wind turbines churn the wind and shake the earth!

After World War II and up to the early seventies only isolated attempts were made in WTG research. Yet, two of the most significant contributions had been during this period. Johannes Juul of Denmark developed a SCIG based WTG in the year 1957 which was a 200 kW machine rated at a wind speed of 15 m/s installed at Gedser which operated until 1968. The Gedser machine is believed to be the forerunner of all later Danish WTG. Ulrich Hutter of Germany built a 100 kW machine in 1957 which had its rated wind speed at 8 m/s and it used fiberglass blades. The machine worked for 11 years and contributed much to the design of the future WTG.

The Development Phases of WTG

In the long first phase of wind generator development (1890–1970) individual attempts by La Cour, Putnam and Juul were of significance but in the absence of an organised and supported programme there was hardly any following up. It was the first oil shock of 1973 that triggered the new energy hunt embracing renewable sources in which wind electricity emerged with the most acceptable economics. As a result, the seventies witnessed government sponsored research and development activities on WTG in many countries. The US as well as the Canadian wind energy programmes commenced in 1973 to be followed by the Swedish, the German and the Dutch. The Danish programme was at a low profile initially in dire contrast to the capital intensive NASA-DOE joint venture in US. Ironically NASA failed to make any significant contribution to the wind power technology development except setting up few impressive large units whereas the Danish efforts turned out to be fruitful with lasting effects. The Danish government adopted a programme to develop wind power in 1977 which eventually gave birth to the Wind Turbine Test Station at *Risø* in 1978. The Danish wind industry took shape in 1980's when many manufacturers satisfied with the performance of 30 kW WTGs started developing larger ones at a fast pace with the prospect of the blooming of global market.

The second phase of WTG development spanned over 10 years from 1970 and then the third took over in the eighties. The age of true commercialisation of wind electricity generation ushered in with molding its twin growth – WTG manufacturing on one side and windfarm development on the other – was significant of the third phase activity. The unit capacity of the WTG touched a Mega Watt by the turn of the century, and a dozen MW today.

The New Generation WTGs

The fourth phase of WTG development that commenced with the early years of 1990s brought in for the first time concern for quality performance. Variety in topology of the technology was an early attempt in this phase. U.S. Windpower came out with their *Kenetech KVS-33* model which used an asynchronous link between the generator (two parallel units of SCIG) and the grid. The asynchronous link, which is a DC link converter employing IGBTs, permits reactive power flow in the reverse direction but maintains the grid power at any desired power factor. It is a variable speed WTG with a wide rotor speed range – such topology is known as variable speed induction generator (VSIG). *Kenetech,* who tried to control their market price filed for bankruptcy in 1996; it is unfortunate that irrespective of massive research on that technology, the wind industry does not own it.

Enercon of Germany soon joined the race with their *E-30* model that also comprises the asynchronous link but uses a permanent magnet synchronous generator (PMSG) instead of SCIG. The ring-shaped generator is directly coupled to the wind rotor without a gear and therefore the nacelle has an aerofriendly shape apart from reduced weight. The asynchronous link in this model regulates voltage and frequency and always match them with the grid values. There are several manufacturers today offering PMSG of varying size.

Realising the relative merits of doubly fed induction generator (DFIG), *Windtec GmbH* developed a 600 kW prototype WTG in 1996 employing the slip power recovery scheme. The DFIG has asynchronous link to the grid only on the rotor side while the stator is directly linked to the grid. It also compensates for the VAR drain without using capacitors. DFIG had its first trial in the German programme of Growian I at Hamburg in 1982. It was the largest WTG made in the twentieth century, having a rotor diameter of 100 m and a rated capacity of 3 MW. With its giant size and ignominious weight, it turned out to be an aerodynamic failure. However, DFIG today is the most popular WTG technology and it has the maximum count on field as well as in production.

The asynchronous type WTGs, both DFIG and PMSG, are classified as variable speed machines, whereas SCIG is called a fixed speed machine, considering the range over which the rotor speed varies corresponding to the operating range of wind speed. The variable speed operation brings in extra energy conversion, because it has higher average efficiency than the fixed speed technology. The major advantage of a variable speed WTG (VSWTG) over the fixed speed WTG (FSWTG) is illustrated below.

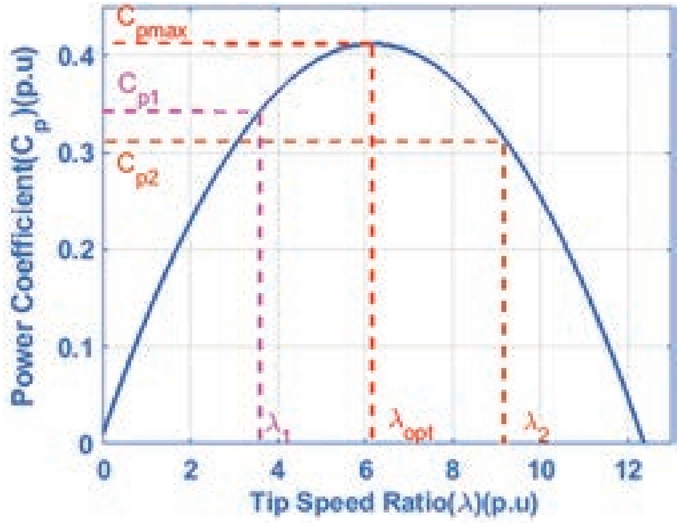


Figure 2: Typical Wind Turbine Characteristics

The generic wind turbine (WT) characteristics, shown in Figure 2, is the plot of its Power Coefficient, C_p, against the Tip-Speed Ratio (TSR) λ; C_p represents efficiency at which power in the wind is converted to mechanical power output of WT, and, TSR is the ratio of the tip speed of the blades to the wind speed. Tip speed is proportional to the rotor speed, which is when kept constant, TSR varies widely yielding low average value of C_p. Upon varying the rotor speed effectively, TSR variation can be contained in a lower range that yields a higher average efficiency. The rotor speed variation is significantly at the command of the electric generator and its control while maintaining synchronism with the grid.

λ_{opt} is the unique value of TSR at which the WT operates at its maximum efficiency of C_{pmax}. For any other value of TSR, for example at λ_1 (that is less than λ_{opt}) and at λ_2 (that is higher than λ_{opt}), C_p is less than C_{pmax}. It therefore suggests the WT to have a varying rotor speed to retain both TSR and C_p at the respective optimum points. In other words, if the turbine speed is allowed to vary proportional to the wind speed variation, then it is possible to maximize the wind electricity generation at any site and in turn maximize the profitability. Operation of WT at C_{pmax} is termed as maximum power point tracking (MPPT) in a WT powered system. However, most commercial models of DFIG and PMSG based WTGs in the market do not possess MPPT facility. Yet, with whatsoever variation in the rotor speed of any VSWTG, it will have a TSR variation less than that of a FSWTG; as a result, the former will register higher production than the latter at any site. The variable speed operation helps in reducing mechanical stress on the rotor blades too.

One should, however, not think that WTG can have the MPPT for its entire range of operation. WT has to operate at a continually decreasing C_p for wind speeds ranging from the rated wind speed, V_r, to the cut-off wind speed, V_o, in order to keep its power output constant for wind speeds between V_r and V_o, and it demands the corresponding values of TSR off λ_{opt}. Therefore MPPT is a requirement in WTG only from the cut-in wind speed, V_c, to V_r. The V_c, and V_r of a WT being typically around 3 m/s and 12 m/s respectively the asking variability in rotor speed of the generator is to the tune of 300% to 400% from the no load state to the full load operation. As such, a comprehensive MPPT demands matching between the torque-speed characteristics of the WT and the generator. The generator coupled to the WT, with or without gear, has to run at the same shaft speed (or at a shaft speed decided by the gear ratio, if applicable) as suggested by λ_{opt} of the WT and extract the maximum power from the WT at any wind speed below V_r. Above all, extraction and delivery of the maximum available power can be realized only if a suitable power flow control is incorporated in the grid-tied inverter of the WTG, as reported by researchers of Amrita School of Engineering, Coimbatore, in their recent publication in *Wind Energy*. PMSG is preferred to DFIG when MPPT is to be embedded in WTG system because of the wide range of operational speed of PMSG in the asynchronous mode.

The Future Generator Options

Haliade-X 12 MW, the world's largest WTG today, installed recently in Maasvlakte-Rotterdam, Netherlands, is a 12 MW machine with features like 220 m rotor, 107 m blade (the longest ever manufactured), 65% capacity factor (the highest ever claimed in the industry), and, 67 GWh of annual electricity production (AEP). It is a direct-drive PMSG with its outer diameter roughly matching the nacelle's 11m width.

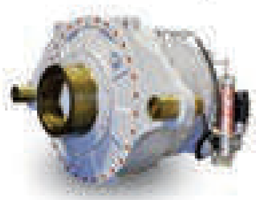
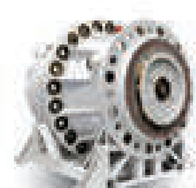
Yet, the choice of technology between DFIG and PMSG is complex. Rare earth magnet used in PMSG is not only expensive, but also environmentally unfriendly. The presence of slip rings and brushes is a handicap in DFIG. That is why Brushless Doubly Fed Induction Generator (BDFIG) has now emerged. BDFIG has no winding on the rotor; instead, it has both the synchronous and asynchronous windings on the stator itself – as in the DFIG, the synchronous winding is synchronously connected to the grid and the asynchronous winding is connected through the asynchronous link. Studies on BDFIG have claimed better performance than DFIG in terms of rotor speed range too. Torque ripple had been a design challenge for BDFIG, like the Switched Reluctance Generator (SRG is yet another WTG candidate that is in waiting for long), but recent research claims solution through improved stator winding design.

Figure 3: Doubly Wound Stator and Specially Designed Rotor of 3.5 kW BDFIG Prototype Developed at Amrita Vishwa Vidyapeetham, Coimbatore

A 3.5 kW BDFIG prototype has been designed and constructed by a team of researchers at Amrita School of Engineering, Coimbatore, recently. Upon testing with a WT emulator the BDFIG prototype showed 67% change in rotor speed, between the no load and full load conditions, against 30%, which is usually claimed by commercial models of DFIG.

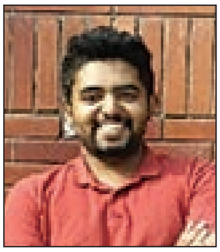
WTG Performance Index

What is the apt performance index of a WTG on field? Manufacturers often campaign for quality performance in terms of capacity factor (CF). Theoretically, a high CF can be attained easily by keeping the rated wind speed low, though it demands much large blade length to match the same power rating. Wind Utilisation Index (WUI), which is the ratio of AEP to the annual energy content at the hub height and within the swept area of the WTG at a site, represents energy conversion efficiency on an annual basis. WUI helps to check and compare site-machine matching too. Improvements in technology and increase in hub height are carrying the WUI up above 35%. More than the technology, WUI will be influencing the wind power development of the future, ensuring closer site-machine matching and lower energy production cost.



Wind Farm Asset Management



Jeffy Johnson, Senior Engineer (Industrial Services)
TÜV Rheinland (India) Private Limited, Bangalore

Wind energy industry more often than not stresses upon the certification and construction phases of a project until commissioning. That said; efficient management of the assets is also the key to realizing the maximum returns on owners' investment. The cumulative experience from global wind energy industry experience shows that insufficient management of wind turbine assets during their O&M phase alone could result in a lowered annual energy production as much as up to 40%. Therefore, an effective and efficient asset management strategy for wind farms should factor in the actual ground conditions and operational performance indicators of the assets which make the strategy a multi-faceted one.

Typical lifetime of an onshore wind turbine is anywhere between 20 and 25 years. Maintaining optimum efficiency level of operational wind turbine assets is an aspect that has been continuously debated upon in wind industry circles. The point is of paramount importance at the moment considering a good percentage (~10 GW) of our existing installed capacity has crossed 60–70% of their design lifetime.

It is need of the hour for the wind industry to largely adopt predictive maintenance into their O&M approach so that assets' operation and energy generation be optimized by factoring in the behavior of repeated alarms and errors generated by the wind turbines through their SCADA system. One of the service providers' industry research shows that onshore wind turbines come under at least one major component failure per year resulting in a minimum of 4 days of turbine downtime and significant energy losses during this time. Adoption of fine-grain predictive maintenance and analytics making use of FTT and OPC architecture (Object Linking and Embedding for Process Control, which is essentially an interface for real time data transfer) data can have a positive impact in terms of simulating fault progression thereby giving the owner an estimated timeline to act, well before the probable failure.

Another debate on sharing of SCADA Data continues to cripple the rate at which wind industry is benefitted. Although improving data transparency and availability will help enable synergies between different verticals thereby helping in efficient benchmarking across WTG models, it is also equally, if not more, important that the SCADA data received is lossless and of very high quality which can hence be leverage upon to perform useful analyses.

All the hype in the current market about employing machine learning and big data analytics is, without a doubt, blowing the winds in the right direction. However, what also needs to be kept in mind is that these methods would need to be equipped to cater to the actual problems of industry, such as early-on fault detection, deeper root cause analysis and earlier signaling of the need for a component replacement, rather than providing a generic picture. There is a need to quantify the performance improvement on wind turbine assets which could then realistically quantify its effect on profit.

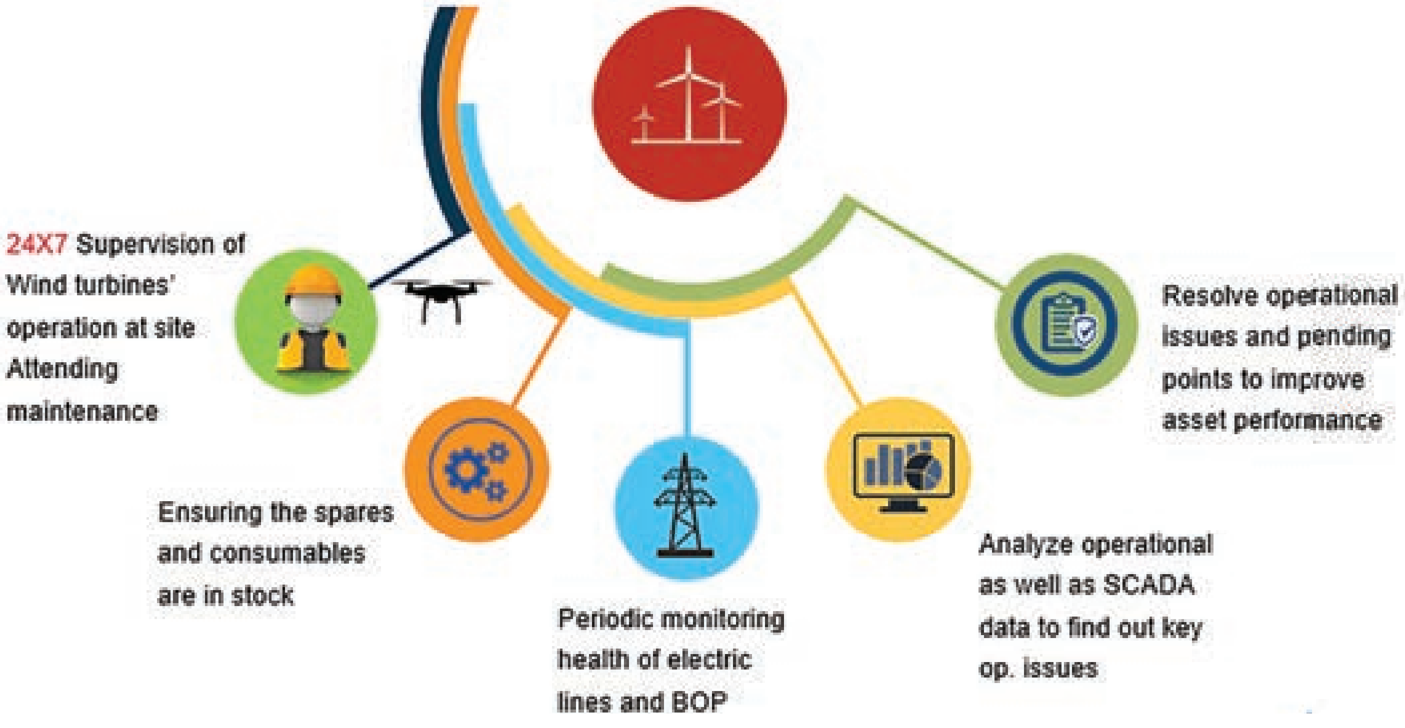
Though employing data science and operational data analytics for fault prediction and maintenance scheduling are still at nascent stage, continuing this push will spring incremental improvements in the turbine performance through.

- Widening opportunities for competitive advantage
- Gradual lowering of costs of O&M and lost yield, as parts can be replaced prior to catastrophic failure

For the betterment of wind industry, it is becoming increasingly important for regular and comprehensive O&M approaches to be supplemented with SCADA data based analytics tools so that the staggering O&M costs may be tamed by planning parts' replacement well before costly catastrophic failures and fine grained root cause analyses. This approach can also be vouched for since it is not unheard of, 30+ years of turbine lifetime in case of wind turbines operational in certain parts of the globe which is distinguished with an efficient, result oriented and multi-faceted asset management strategy coupled with the ongoing O&M.

There is a slightly steep industrial learning curve that needs to be scaled by budding asset management firms that are focusing on wind data analytics and machine learning. This could be supported by manufacturers and turbine owners by facilitating high quality SCADA data from their wind turbine assets to gain deeper and actionable insights into their asset performance. Also individual components, at least the cost-intensive ones such as gearboxes could be integrated with built-in data analytics and supplied as standard.

The technical services management in post-commissioning phases needs the following types of supervision and maintenance work. This work needs long experience in the sector coupled with the current trends in big data analytics and machine learning. Periodic drone based inspections are also needed. TÜV Rheinland can help Wind Turbine Owners through Turbine management and analytics.



The Technical Services Management in Post-Commissioning Phases

Emerging Technology – Craneless Technology

Anderson Samuel
Head - Wind Business

Vasanth Balasubramanian
Business Development

Windcare India Private Limited

Recent years in the Indian Wind market, there is steep increase in turbine capacity, higher hub height even up to 140m and Rotor diameter ranging to 140 meters. Upon the huge investment, investors really being facing the challenges due to the advent of the low tariff – result of reverse bidding policy implemented nationwide and in addition to that of the penalty deviation mechanism implementations in some regions.

Forecasting & scheduling techniques are fine enough & support the utilities to manage their operations as much as possible against the existing challenges such as operating & maintenance cost, newer technology and its updates, spares reliability & its cost, transmission losses, grid connections, natural calamities, etc.

As a result, to overcome all these hurdles & troubles, investors ranging in all categories, Original Equipment Manufacturers (OEMs), Independent Power Producers (IPPs) and Independent Service Providers (ISPs) are looking forward for the cost reduction in terms of operation & maintenance and innovation of new technology to maximize the yield with minimal operating cost.

The improper wind pattern and severe lightning's strikes affects the rotor blade parts, gear box & generators which is the major common trouble facing now a day's results in increasing the overall maintenance cost. Every year more than 7% of wind turbine blades failures and 5% of generator, gear box breakdowns are recorded consuming the major operating cost & breakdown period.

Fulfilling the investors OEM's, IPP's & ISP's long-term expectation over the years, in search for the innovative solution to make this green energy business much greener than other renewable business with less operation & maintenance cost, a newer incredible and innovative solution called "Craneless Technology" has been invented.

This technology arises from the pressure on all power players to reduce the cost of the conventional practice of maintaining the WTG's. The incurring cost for mob/de-mob, fuel consumption, access of pathway, endangering of environment comparatively makes the investor to think on alternatives.

Such an alternative solution to reduce the incurring cost is the "Craneless Technology", this technology uses the method of de & re erection of huge & heavier components such as single blades, blade bearings, gear box, generators, transformer from the nacelle & even the entire rotor can be done with a quick assembly of derrick's, customized tools & skilled experts.

Cost for such major component replacement by conventional crane method consumes the major portion costing from crane end including mob/de-mob, fuel consumption, access of pathway, Right of Way (ROW). If it is of the blade repair, 20% of cost alone is the actual repair cost, 80% cost will be the crane hiring cost. Gear box replacement activities consumes 40% of actual repair cost & whereas the 60% of balance cost to be paid for crane rental. In case of generator failure 20% is the actual cost is for generator repair rest and 80% is to be paid as the crane end.

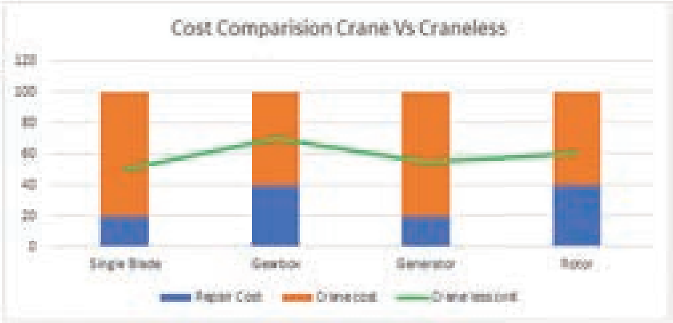
Maintenance cost by means of traditional crane method for such major component replacement results in increase of over all operation cost, whereas on the other hand over all maintenance cost by craneless solution it can be reduce close to 60% than existing method of practice.

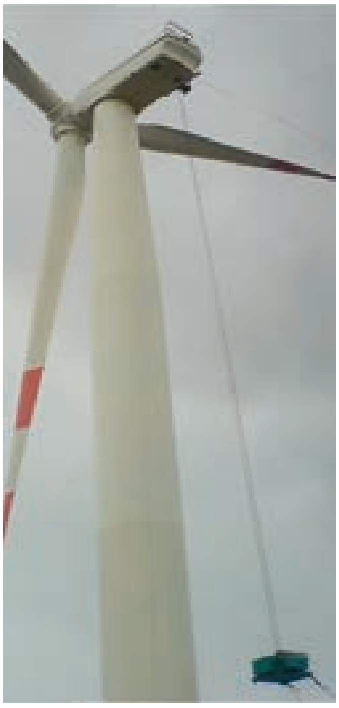
Highlight of Craneless Technology

- Minimize the use of cranes and its related cost.
- Applicable & adoptable to all WTG's ranging from KW to MW.
- Green Technology
- Ease of access to WTG location
- Reduce the down time & increase the availability

Craneless activity	Working range (up to)	Working Limit (up to)
Single Blade	10 m/s	15 ton
Generator	12 m/s	16 ton
Gear box	12 m/s	20 ton
Rotor	8 m/s	55 ton
Transformer	12 m/s	12 ton

It reduces the operating & maintenance cost of WTGs by alleviating the drawbacks associated with the traditional crane solutions occurred during major components breakdown. Future of WTG's maintenance relies on this technology which will empower & lightning India. Such a boom technology will make India proud internationally by being competitive against all the existing technologies which comprises of all international standards & quality in it.



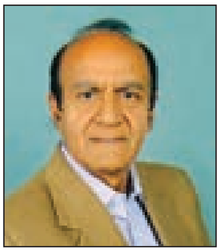


Fruit of the long Experience

We are in the industry since 1998 and from that period onwards we are optimizing the O&M cost, which is always the hot topic in the industry as the O&M cost decides and makes the life span of the turbines feasible and the project viable to investors.

We have developed this craneless innovation in 1999 while working with smallest 225 kW, 30m height turbines and over the past two decades touched working up to large scale of 2.5MW 140m height turbines, thus resulting in the cost reduction. Apart from the craneless and patented innovation, we are also doing more innovations in the field of blade inspections, repairs and many other services.

Generators for Wind Turbines and their Trends



Dr. Shambhu Ratan Awasthi, Director
Rabindra Nath Tagore University, Bhopal

A generator converts mechanical energy into electrical energy. In wind turbines, 3-phase induction or synchronous type generators are used. Earlier, mostly, the induction generators were used to be coupled to the wind turbines through gearboxes. A very small variation in speed can be obtained and hence induction generators are also called fixed speed type.

With the advent and adoption of AC-DC-AC electronic converters, directly coupled induction as well as synchronous generators are increasingly used.

The speed of revolution of a synchronous generator depends on the grid frequency and number of poles. It is given by the following equation:

$$\text{Synchronous speed (rpm)} = (120 \times f)/p \qquad (1)$$

Where, f is the grid power frequency (Hz)

and p is the number of poles.

There are various similarities and dissimilarities in two types of generators as given in Table 1.

Table 1: Induction and Synchronous Generators[1]

Parameter	Induction Generator	Synchronous Generator
Stator	Stators of the induction and synchronous generators are similar i.e. same stator can be used for induction or synchronous generator	
Rotor Types	squirrel cage	cylindrical
	wound or slip ring	salient pole
Speed of Rotation	Above synchronous speed. (operates as induction motor below synchronous speed)	At synchronous speed.
Variation in Speed	Small variation in speed (also called fixed speed type).	Large variation in speed is obtained using AC-DC-AC converter. (also known as variable speed type)
Excitation	- Excitation power is drawn from the source to which it is connected. - The source is the power grid in grid interactive WEGs.	- Variable excitation is fed to field winding to magnetise the poles (conventional electromagnets) - The poles are magnetized at fixed excitation (permanent magnets)
Power Factor and Voltage	No control on power factor and voltage. Operates at lagging power factor.	Voltage and power factor are regulated to match with the grid parameters.
Cost	Low	High

Induction Machine

The induction machines operate on induction principle. It operates as a motor below synchronous speed and as a generator above synchronous speed. The rotor current is not induced at synchronous speed i.e. it cannot be operated at synchronous speed. The difference between actual speed of rotor and speed of rotating magnetic field of stator (synchronous speed) is called 'slip'. The slip of induction machine varies with the load.

The stator winding of induction machine is connected to the electrical power source. It draws magnetizing power from the grid and creates a rotating magnetic field which induces magnetic field in the rotor. The operation of an induction machine is due to an interaction between the two magnetic fields i.e. rotating magnetic field in stator and rotor magnetic field.

Squirrel Cage Induction Generator

The slip is given as a percentage of synchronous speed which varies from 1 to 2%. The rotor winding is built of copper bars


Boosting turbine performance and profitability
SKF is designing and developing bearings, seals, condition monitoring systems, and lubrication systems that enable more cost-effective wind energy generation. Working together with original equipment manufacturers and wind farm operators, SKF engineers provide dedicated solutions that can optimize the reliability and performance of new and existing wind turbine designs.
SKF's dedicated wind turbine solutions can help both turbine manufacturers and wind farm owners to:
• Increase energy production
• Increase turbine performance and reliability
• Reduce operating and maintenance costs
• Reduce lubricant consumption
• Minimize environmental impact
• Reduce energy losses
• Decrease warranty claims
• Reduce time to market
• Customize solutions
For these and more solutions, visit www.skf.com/wind
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Mahavir Kanwade
Manager-Application Engineering SKF India Limited
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which are brazed at both the ends to the end rings as shown in Figure 1. Thus, rotor winding of a squirrel cage type induction machine is not accessible for further electrical connection.

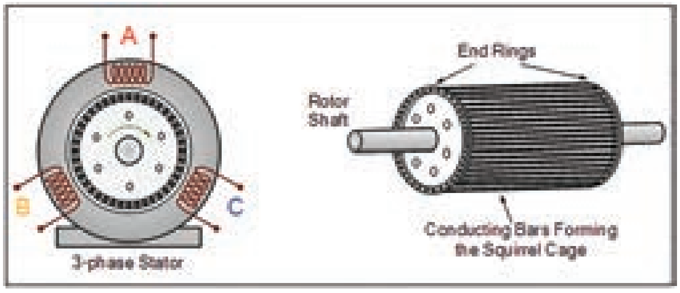


Figure 1: Squirrel Cage Induction Generator[2]

Wound Rotor Induction Generator

The stator and rotor both have three-phase windings. The slip rings are provided on rotor shaft on which three-phases of the rotor winding are terminated. The external resistances are connected in series with each phase of the rotor winding. The variation in speed is obtained by varying external resistances with the help of fast-acting power electronic system that helps to obtain slip up to about 10%.

In the past, dual speed induction machines have also been used in which two speeds of rotation are obtained by altering the number of poles. It is done by changing the field winding connections to select one of the two combinations of number of poles. Thus, as per the wind speed, the induction machines are operated at suitable speeds of rotation. Thus, at low and high wind speeds, one of the two sets of poles is selected. However, the dual speed induction machines are no more used in new installations.

Synchronous Generator

The synchronous generators are classified as below on the basis of their excitation system:

- synchronous generators with electromagnets (variable excitation is fed from external DC source)
- synchronous generators with permanent magnets (fixed excitation is fed from permanently excited magnetic poles)

In a synchronous generator, the magnetic field of rotor aligns itself with the rotating magnetic field created by three-phase stator winding. The generator voltage is compared with the grid voltage at short time intervals. Depending on difference in two voltages, DC excitation is supplied to the field winding. The synchronous generator can be operated at lagging or leading power factors.

In a permanent magnet type generator, the permanent magnets are used. The voltage, power factor and reactive power cannot be controlled due to fixed magnetization of permanent magnets.

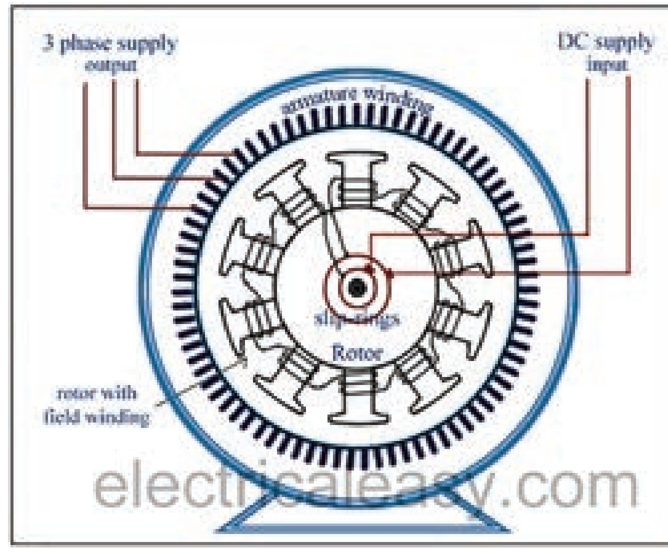


Figure 2: Salient Pole Synchronous Generator[3]

Trends

The trend in wind turbines has been for higher and higher rating. The turbine output is proportional to the cube of wind speed. The wind speed increases as we go up above the ground. Hence, the researchers and designers keep on developing the turbine designs for higher hub heights to obtain higher turbine output. The turbine rated speeds are low. The generators coupled to the turbine are responsible for providing quality electrical output. In the competitive market, there is a need of innovative design of cost effective generators to suit the turbines. A few such wind electric generators are discussed next.

Onshore 10 MW Turbine

The SeaTitan™ 10 MW wind turbine designed by American energy technologies company AMSC is a direct-drive turbine and is designed for a hub height of 125 m, rotor diameter of 190 m and rated speed of 10 rpm. The winding is made of high temperature superconducting material. It makes the generator much smaller and lighter than a conventional wind electric generator.[4]

The superconductor generator has a large air gap to eliminate issues with tolerance, deformation and rare earth material availability. The generator is integrated with the turbine and decoupled from the load-carrying components. Generator torque is transferred directly from the stator to the mainframe.

Amperium conductor is used instead of copper for the HTS rotor. The current carrying capacity of Amperium is over 100 times more than that of copper of the same cross-sectional area. It makes the generator compact, lighter and more efficient than conventional generators. It provides the highest known power-to-weight ratio. This reduces the cost associated with the supporting tower, foundation, and installation.

Generator Specifications[4]

Type	:	HTS synchronous
Rated driving power	:	12,000 kVA
Rated generator speed	:	10 rpm
Number of poles	:	multi-pole
Cooling	:	cryogenic and water cooling
Converter type	:	IGBT, 4-quadrant
Generator rated power	:	0.95 inductive to 0.95 capacitive at 690 V ph-ph

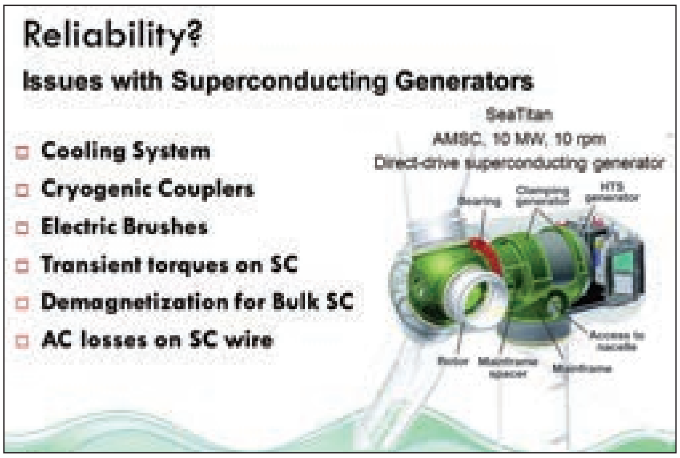


Figure 3: Issues with Superconducting Generators[5]

Offshore 10 MW Turbine

A 10 MW WEG model ST10 for offshore wind turbine has been designed and developed by Sway Turbines AS, Norway. It has a hub height of 90 m, rotor diameter of 164 m and rated speed of 12 rpm. The blades are mounted on 'A-frame' support structure to which the outer rim of the generator rotor is connected as shown in Figure 4. The turbine has a direct driven, 3.5 kV permanent magnet synchronous generator with ironless stator core. Which reduces weight and cost. The turbine is suitable for fixed as well as floating type foundations.

Figure 4: A 10 MW WEG with Ironless Stator Core[6]

12 MW Offshore Wind Turbine

General Electric is manufacturing a 12 MW offshore wind turbine, Haliade-X.

The first nacelle from its production site in Saint-Nazaire, France has been supplied to an onshore testing site in the Netherlands. A second nacelle will be tested offshore in U.K. The commercial shipments is to begin by mid-2021.

Figure 5: Nacelle of a 12 MW Wind Turbine[7]

The maximum capacity commercially wind turbines in the market are up to 10 MW. The large diameter of Haliade-X's rotor increases the capacity utilization factor of the turbines and results in enhanced power generation.

Conclusion

The generators of a wind turbine system are responsible for providing quality electrical power. The generators have to match with the increasing ratings and sizes of turbines. In a competitive environment, innovative approach is necessary to continuously develop the compact, light weight, reliable and cost effective generators to suit turbines.

The flying (kite) wind turbines are likely to become a reality in not too far future which necessitates innovative development of light weight and higher voltage flying generators for low current power transmission to earth.

References

1. Awasthi S.R., Wind Power: Practical Aspects. TERI Press, New Delhi
2. Alternative Energy Tutorials, Induction Generator as a Wind Power Generator, http://www.alternative-energy-tutorials.com/wind-energy /induction-generator.html
3. Alabbad, N.N. Construction – Synchronous Generator. https://sites.google.com/site/nashmiadviserengineerinele/about-me/construction-synchronous-generator
4. SeaTitan 10 MW wind turbine https://www.amsc.com/wp-content/uploads/wt10000_DS_A4_0212.pdf
5. Keysan J.,2012. Slideplayer. Superconducting generators for large wine turbines. https://slideplayer.com/slide/6371538/
6. Vries. E.D. 2012. Sway turbine's 10 MW turbine, https://www.windpowermonthly.com/article/1155881/close-sway-turbines-st10-10mw-turbine
7. Stromtsa K.E. gtm. 2019.12 MW GE wind turbine https://www.greentechmedia.com/articles/read/ge-finishes-first-nacelle-for-12mw-haliade-x-offshore-wind-turbine#gs.u4dpzu

LTCA Approach to Overcome Potential Gear Failure Modes while Re-powering Windmill Gearboxes

Mahendran M., General Manager - Design & NPD
Shanthi Gears Limited, Coimbatore

Introduction

The evolution of gear design engineering, material science and heat treatment of alloyed steels, precision gear grinding machines have provided more optimal gearing for wind mill gearboxes. The advanced design computations and simulations helped the industry to size compact gearboxes, that transmit maximum torque within the given tight boundary. Meantime, maintenance cost of aged windmills particularly gearboxes became costlier due to their unexpected failures by accumulated fatigue damage cycles and OEM's spare-parts pricing strategy. This scenario has encouraged most of the legacy windmill operators to repower the windfarms with same foundation and tower with higher power density gearboxes while supported by latest blades designed with aerodynamic profiles and energy efficient generators. This article is about how to overcome the potential gear failure modes of gears using the Loaded Tooth Contact Analysis while repowering the windmills with higher capacity gearboxes.

General Considerations

Gearbox is a critical component in every wind turbine and if we consider gears as heart of the system, then lubrication serves as the lifeblood inside the gearbox to keep its life alive. Hence, it is essential to ensure the gear design with proper lubrication by doing condition checks for the trouble free operation of the gearboxes. The important activity while repowering is to evaluate the captured wind load history and develop the Design Load Cases (DLC) and Load Duration Distribution (LDD). The maintenance log prepared during the past will be an informative database to understand gearbox related issues, and to overcome similar issues while upgrading the existing gearbox.

Gearbox Design Criteria While Re-powering

The re-powering design activities should be carried out by reputed organizations and qualified technical personnel. The up-gradation may need re-certification to satisfy requirements of Germanischer Lloyd (GL) guidelines. Hunting teeth combination shall be preferred to avoid the frequency of same pinion teeth engaging with same teeth in Gear. The optimal size (module) gears could be selected for better root strength and pitting strength (ISO 6336). Shaft strength analysis (DIN 743) and bearing life calculations (ISO 281) ensures the adequate safety of gearbox components fitted in the housing. Maintaining high-level accuracy in gears during profile grinding (DIN 3961-Q5) and Precise machining of housing bores with high-level concentricity ensures the smooth meshing of teeth both at no load and at loaded condition.

Load Spectrum

The wind loads are fluctuating in nature and varies transiently with speed and intensity. Windmill gearboxes are subjected to various loads and speeds in operating nature. The gearbox fatigue load is considered with a load spectrum, which contains elements of power, speed, torque, time duration information in several bins. The gear fatigue life with load spectra is calculated based on Palmgren-Miner rule in compliance with ISO 6336, Part 6. Load spectrum calculation has to be computed for required safety factors for pitting, tooth breakage and scuffing as per ISO-6336 standards using appropriate software tools.

Loaded Tooth Contact Analysis (LTCA)

The Loaded Tooth Contact Analysis (LTCA) is one of the most powerful methodologies available with gear calculation software, which analyses the tooth contact characteristics under various load conditions. This analysis is done with the consideration of housing, bearings, shafts and gear body deformation to find best values for micro geometry parameters. Power losses, EHD lubricant film thickness, micro pitting and scuffing calculation are computed based on LTCA results.

LTCA Methodology

The approach of repowering of the gearboxes will be about to optimize and validate the design parameters, in a wide range of operating load spectrum with the simulation of tooth surface behaviour under Hertzian deformation by the following:

- Analyze the macro geometry of the gearbox to comply specification standards by using LDD data, sized for required power in the provided space constraints
- Compute the Loaded Tooth Contact Analysis (LTCA) by simulating and evaluating with various micro-geometry

parameters (profile-lead modifications) and approximated by a cantilever beam model with FEA software

- Develop a computational approach for analyzing the load spectrum and review the quality of the meshing contact by computing non-uniform distribution of load and stress levels
  - along the lines of contact (Transverse load distribution factor)
  - across the gearing face width (Face load distribution factor)
  - elastic deformations and misalignment of the axes of rotation of the pitch cylinders of the mating gear (Mesh Alignment Factor)
- Design iterations and micro-geometry optimization to have Low noise design by ensuring
  - low-level Peak-to-peak transmission error (PPTE)
  - minimized contact shocks due to shaft deflections

Evaluating results and choosing the best solution among various iterations and develop strategies to validate analytical results in test bench/load tests will be challenge in front of the design team, with cost economy in manufacturing.

Design Optimization with LTCA

The LTCA optimization program has been developed with objective function to ensure the even load distribution under given load by iterating micro geometrical parameters. The variables are profile corrections and lead corrections like tip relief, end relief, lead crowning, helix modification. The constraints are shaft deflections, gap analysis by comparing lead variation. The algorithm is a one-dimensional contact (mesh gap) analysis with two-dimensional deflection & torsional analysis as defined in ISO 6336-1, Annex E.

The contact ratio under load shall be the same as the theoretical contact ratio, for the gears with perfectly modified tooth geometry, which includes flank line modifications, crowning to compensate tolerances and profile modifications. The tooth pair gap with contact stiffness $C\gamma\beta$ is illustrated with a spring model. When the tooth flanks are brought together, both flanks have a common contact width $bcal$.

Face load distribution factor KHβ calculation was done based on ISO-6336 with various assumptions on load distribution in the plane of action, at operating pitch cylinder. Based on FVA reports by Weber/Banaschek, tooth pair spring stiffness has been computed with an Analytical approach, considering the following:

- Deformation δ, along with the path of contact
- Three deformation components
  - Bending
  - Tilting
  - Hertzian flattening

This approach also complies with Hooke's law: F=$C \cdot \delta$, where F is restoring force, C is stiffness tensor and δ is deflection parameter.

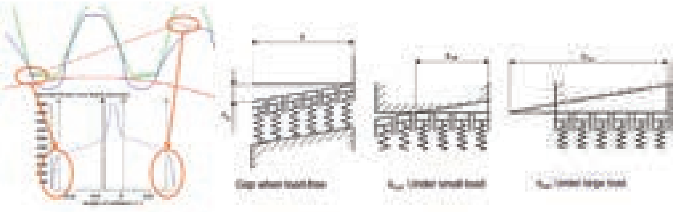


Figure 1: Tooth Pair in Contact as a Spring Model

Design iterations and micro-geometry optimization have been computed to

1. minimized contact shocks due to shaft deflections
2. low-level Peak-to-peak transmission error (PPTE)

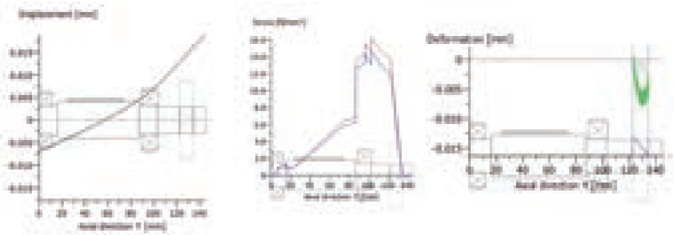


Figure 2: Shaft Deflections & LTCA Analysis

The micro-geometry Optimisation for the LTCA can be performed by using the specific sizing function for the gear modifications. Within the predefined limits, the sizing function ascertains all possible combinations up in multiple sets of modifications and carries out a contact analysis for each variant, by varying loads.

Since contact pattern is strongly depending on load, LTCA results are visualized in radar charts to determine the best option amongst the optimum combinations of modifications.

Spectrum Analysis of Transmission Error

Transmission Error (TE) indicates the variation on the contact stiffness. The amount of TE is determined by the way how the contact point is displaced on the path of contact in μm.

The amplitude of the transmission error is a decisive criterion in determining how quietly a gear unit runs. (PPTE = Peak-to-peak Transmission Error)

Transmission Error is considered to be the primary cause of whining noise in gear boxes. TE curve is important, and a steeper slope in the resultant TE will produce higher accelerations and vibrations.

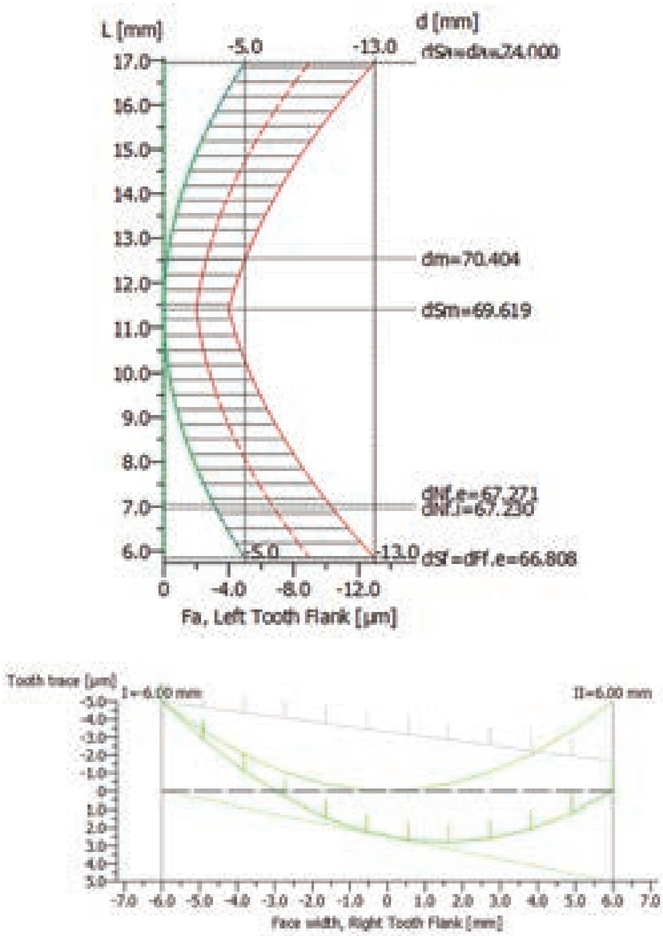


Figure 3: Profile and Lead modification curves thru LTCA Analysis

The gearbox TE is optimized with various load levels and found significant improvement with LTCA analysis.

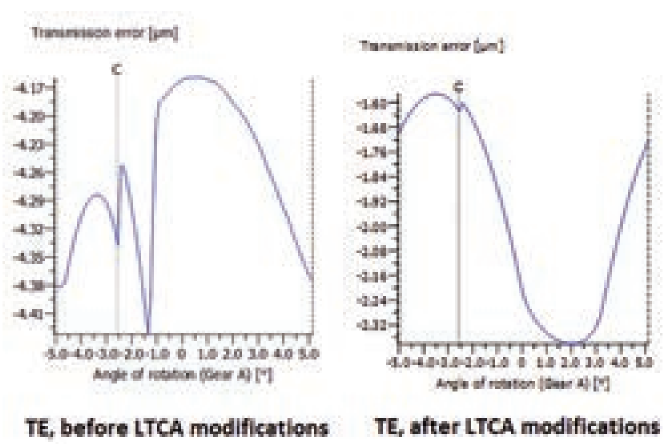


Figure 4: Transmission Error Analysis

Contact Pattern Analysis

The analysis made for the input shaft deflections will show the significance of bending and torsional moments in the system. The amount of contact varies with different load and speed conditions of the turbine blades. The contact pattern could be analyzed for various load level and the spread also visually studied in a graphical pattern.

Since it is uni-directional, active flanks of the gear teeth could be compensated to have full involute contact at the desired range of operating load. The best contact pattern will be in mid of tooth portion and no stress concentration at edges during the selected load levels.

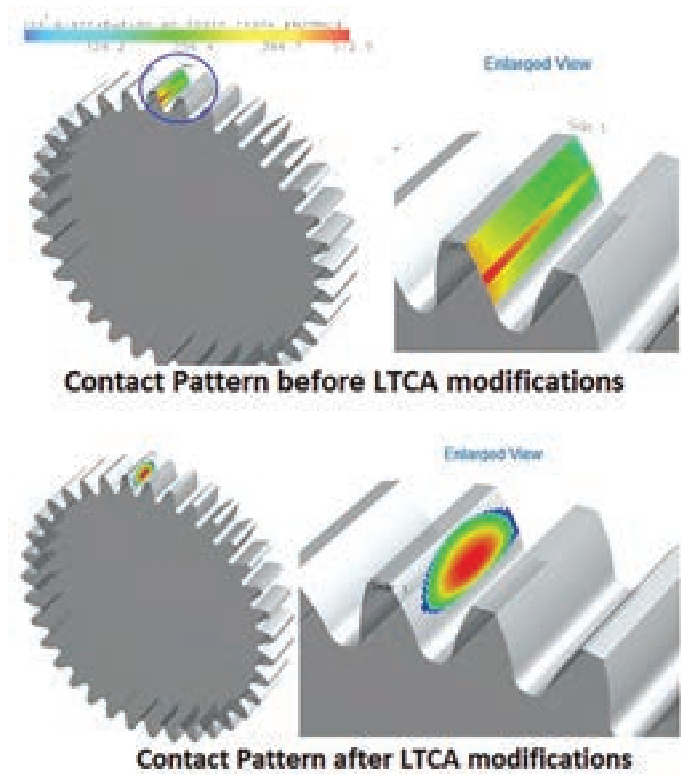


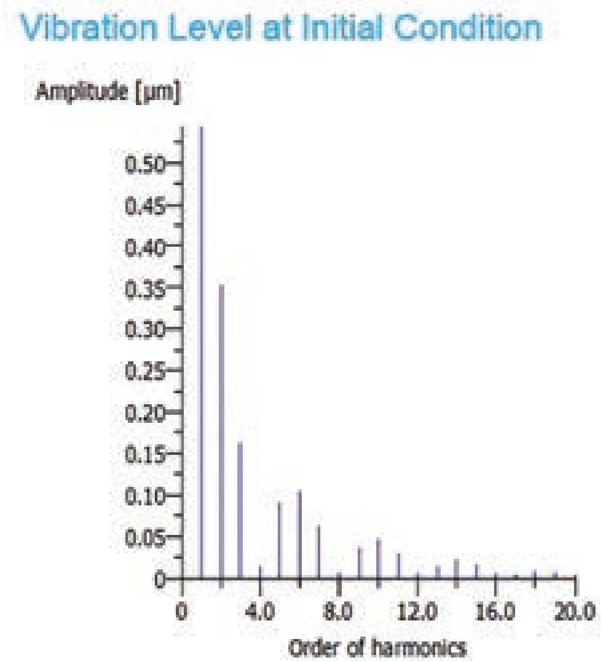
Figure 5: Simulated Contact Pattern with LTCA Design Parameters

Effect of Tooth Modifications on Vibration and Noise

The optimal modification of the tooth profile and lead could be obtained by iterating in a wide range of values in software. The vibration measurements can be taken on housing, near to the bearing positions. The data will be analyzed to understand the effects of LTCA modifications, and the vibrational amplitudes that is related to the input stage gear mesh frequency (product of the number of teeth and the shaft rotational speed) has been improved towards better characteristics with profile and lead modifications.

Harmonic analysis is used to determine the response of the structure under a steady-state sinusoidal (harmonic) loading at a given frequency. An order refers to a frequency that is a certain multiple of a reference rotational speed. In Figure 6, the amplitude in the order of harmonics is compared for vibration

at the initial condition and after LTCA modification, which shows better characteristics with optimal LTCA parameters.



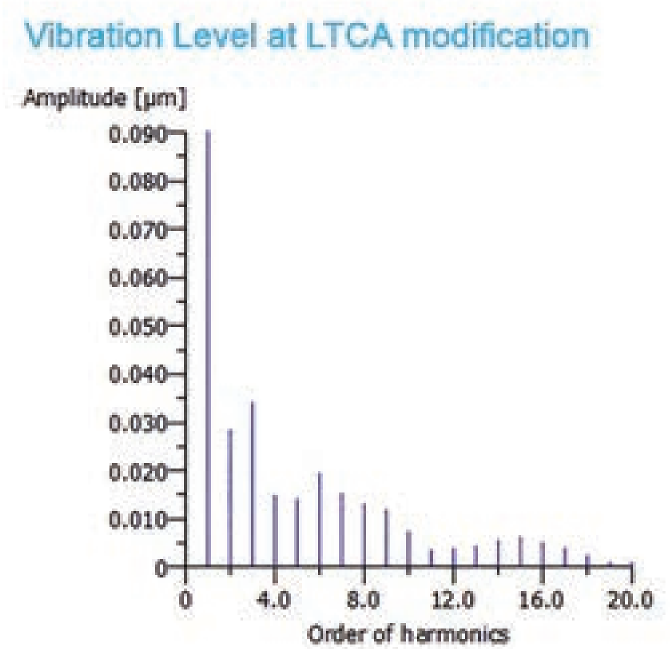


Figure 6: Comparison of Vibrational level at Initial and After LTCA Modification

Summary

Wind turbines are growing in sizes, power capacity, complex instrumentation and fitted with sophisticated condition monitoring devices and SCADA systems. Re-powering with higher capacity turbines by using the same foundation will be more beneficial instead of simply replacing same capacity gearboxes in turbines while high wind potential and blade design is available there. The LTCA approach is very useful tool to improve the performance of the gearboxes during repowering, with iterative analysis on the transmission error and gear mesh stiffness variation to minimize the transmission error under the influence of time varying loads.

References

1. Niemann,***"Maschinenelemente,"*** Band II, Springer Verlag, 1985.
2. Hao Chen, Yu Sun*, Kai Wu , ***"Load spectrum testing and analysis for transmission system of closed high-speed press",*** Nanjing University of Science and Technology, ICTP 2014.
3. ISO 6336, Part 1,"***Calculation of load capacity of spur and helical gears***" ISO Geneva, 2006.
4. KISSsoft; ***Calculation software for machine design***, www.KISSsoft.AG
5. Litvin, F. L.,"***Gear Geometry and Applied Theory***," Prentice Hall, 1994.
6. Weber, E., Banaschek, K., "***Change in shape and Profile modification in straight and helical gears***", Series Drive Engineering 11, 1953.

Snippets on Wind Power

EU Considers Energy Taxes to Counter Climate Change

The European Union is considering new energy taxes, including on the aviation sector, to meet its climate targets, top officials said on 13th September 2019, with Germany calling for "drastic steps" to reduce carbon emissions. Over the last decade, EU countries have led a global shift towards renewable energy and set up the world's largest emissions trading system to price carbon and reduce reliance on more polluting fuels. At the same meeting, German finance minister Olaf Scholz said drastic steps were needed to counter climate change and urged an international approach on the matter. "We are in the process of finding out how we can limit CO2 consumption in agriculture, small businesses or transport," Scholz said.

Source: Reuters, September 14, 2019

Wind Power Regulatory Updates - August 2019

NTPC Issues Tender

NTPC has issued the tender for 1200 MW wind power project with upper cap of Rs 2.85 per unit. (28th August 2019)

RRECL Draft Wind and Wind-Solar Hybrid Policy 2019

Rajasthan Renewable Energy Corporation Limited (RRECL) has come out with Draft Wind and Wind-Solar Hybrid Policy 2019. (29th August 2019) This policy aims to achieve the following targets:

1. The target of 2000 MW Wind Power capacity for fulfillment of Renewable Purchase Obligation (RPO) of State Discoms in respect of wind energy as determined by RERC up to 2023-24. Discoms/RUVNL may procure Wind Energy beyond the RPO as per their requirement and commercial viability.
2. In addition to above capacity, State will Endeavour to develop Wind Power Projects for captive consumption within the State and for sale to parties other than Discoms of Rajasthan within the State and outside the State.
3. Policy also aims to achieve a target of 500 MW up to 2021-22 in the State through Wind-Solar Hybrid.

This policy also aims to promote the Wind Energy with the following:

1. Promotion of Wind Power Projects with Storage Systems
2. Promotion of Repowering of Wind Power Projects
3. Strengthening of Transmission and Distribution Network for Renewable Energy.
4. Promotion of Wind Resource Assessment Programme
5. Promotion of manufacturing industries of Wind Energy Equipments.

MSEDCL Issues Tender

MSEDCL has issued the Tender for 500 MW wind power project with a ceiling tariff of Rs 2.95 per unit. (30th August 2019)

E-Reverse Auction SECI Tranche VIII

E-Reverse Auction was conducted for 440.64 MW of ISTS connected wind project SECI Tranche VIII. The successful bidders are as follows:

CLP = 250.80 MW @Rs. 2.83/kWh

Avikiran Energy/Enel = 189.84 @Rs. 2.84/kWh

The original bid was of 1200 MW but the Reverse Auction happened for 440.64 MW only as the participation was very low. (30th August 2019)

Compiled by: IWTMA Team

Snippets on Wind Power

ADB President meets PM Modi; Pledges $12 bn Support for Flagship Schemes

Asian Development Bank (ADB) President, Mr. Takehiko Nakao, met with Prime Minister Mr. Narendra Modi in New Delhi recently and discussed ways to further enhance their partnership in areas such as renewable energy, solar-pump irrigation, electric vehicle and battery. Nakao said that ADB stands ready to commit more than $12 billion lending in the next three years, 2020–2022, averaging annually over $3 billion for sovereign operations and $1 billion for non-sovereign operations.

Source: E T Energy World, September 02, 2019

Snippets on Wind Power

Govt. Planning Mega Renewable Energy Projects like UMPPs

The government is planning large renewable energy projects like the coal-based ultra-mega power projects (UMPPs) through the public-private-partnership route. The renewable power projects may include any renewable source of generation or a combination of them. The plants are likely to be 1,800 MW in capacity, which can be spread over three areas of 600 MW each, and the power purchase agreements (PPAs) will be for 25 years, a senior government official said. The government is planning to allocate the responsibility of site identification to all central public sector undertakings (CPSUs) in the energy space, including NTPC Ltd, SECI, Power Finance Corp and NHPC Ltd. Each CPSU may be given charge of two-three states. They will float joint ventures with the state governments and set up special purpose vehicles (SPVs). The states will help the SPVs secure land and regulatory clearances. The Centre is working on two-three models for sharing of profit between the CPSUs and the states. A major relief to the renewable projects would be that the connecting power transmission line will be treated as national asset, relieving it from any pangs in clearances.

Source: ET Bureau, August 13, 2019

Govt to Relax Lease Rent of Wind Power Projects

The Union Environment Ministry has decided to do away with the mandatory charging of lease rent of Rs 30,000 per MW from wind power projects. Currently, to establish wind power project over forest land, the existing procedure requires payment of mandatory charges for compensatory afforestation and Net Present value (NPV). In addition to mandatory charges, the wind power companies had to pay additional lease rent of 30,000 per MW.

Source: The Pioneer, 23 August 2019

Wind Energy Sector Needs Market-Led Incentives: IIM-A

A paper titled 'Financial support vis-à-vis share of wind generation: Is there an inflection point?' in journal Energy authored by Dipti Gupta, Abhiman Das and Amit Garg studied the financial support model of 15 countries and 10 states of the US between 2006 and 2017. A paper authored by the IIM-Ahmedabad (IIM-A) researchers suggested that wind energy in India has become market competitive and thus it should be pulled more by the market forces rather than being pushed by the government incentives.

Source: TNN, August 27, 2019

'World's Largest Tech Investor' Puts US$110m Bet On Energy Storage Using Concrete

The world's largest technology investor, SoftBank's Vision Fund, has made its first investment in an energy storage company, betting US$110 million on Swiss start-up Energy Vault. Energy Vault has developed a form of energy storage inspired by pumped hydropower stations, which rely on the movement of water to store and discharge electricity. In its solution, concrete blocks weighing 35 metric tons are lowered up and down an energy storage tower, storing and releasing energy. Energy Vault's proprietary cloud-based software autonomously controls the cranes lowering and lifting the blocks. The software relies on a combination of predictive intelligence and algorithms that account for a variety of factors, including supply and demand, grid stability, and weather. It will be erecting its first 35MWh tower in northern Italy this year, and it has an agreement to deploy another for India's largest integrated power company The Tata Power Company.

Source: Energy Storage News, 15 Aug 2019

Renewable Energy Can Generate Billions of Dollars in Health Benefits

Researchers at MIT are foreseeing a healthier Rust Belt as a result of renewables. Particulate matter, or soot, can adversely affect respiratory and cardiovascular health. But if those states switch to more renewable energy, air quality will improve. As the pollution rates diminish, so should lung cancer, heart attacks, and strokes among people living there.

This could also reduce the medical bills and lost wages associated with those health effects, which leads to their estimated benefits of $4.7 billion in 2030 if current standards are adopted. This is something that medical researchers call a co-benefit of taking action against climate change.

Source: The Verge, Aug 15, 2019

Compiled By: **Mr. Abhijit Kulkarni**
Business Unit Head - Energy Segment
SKF India Ltd, Pune and
IWTMA Team

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