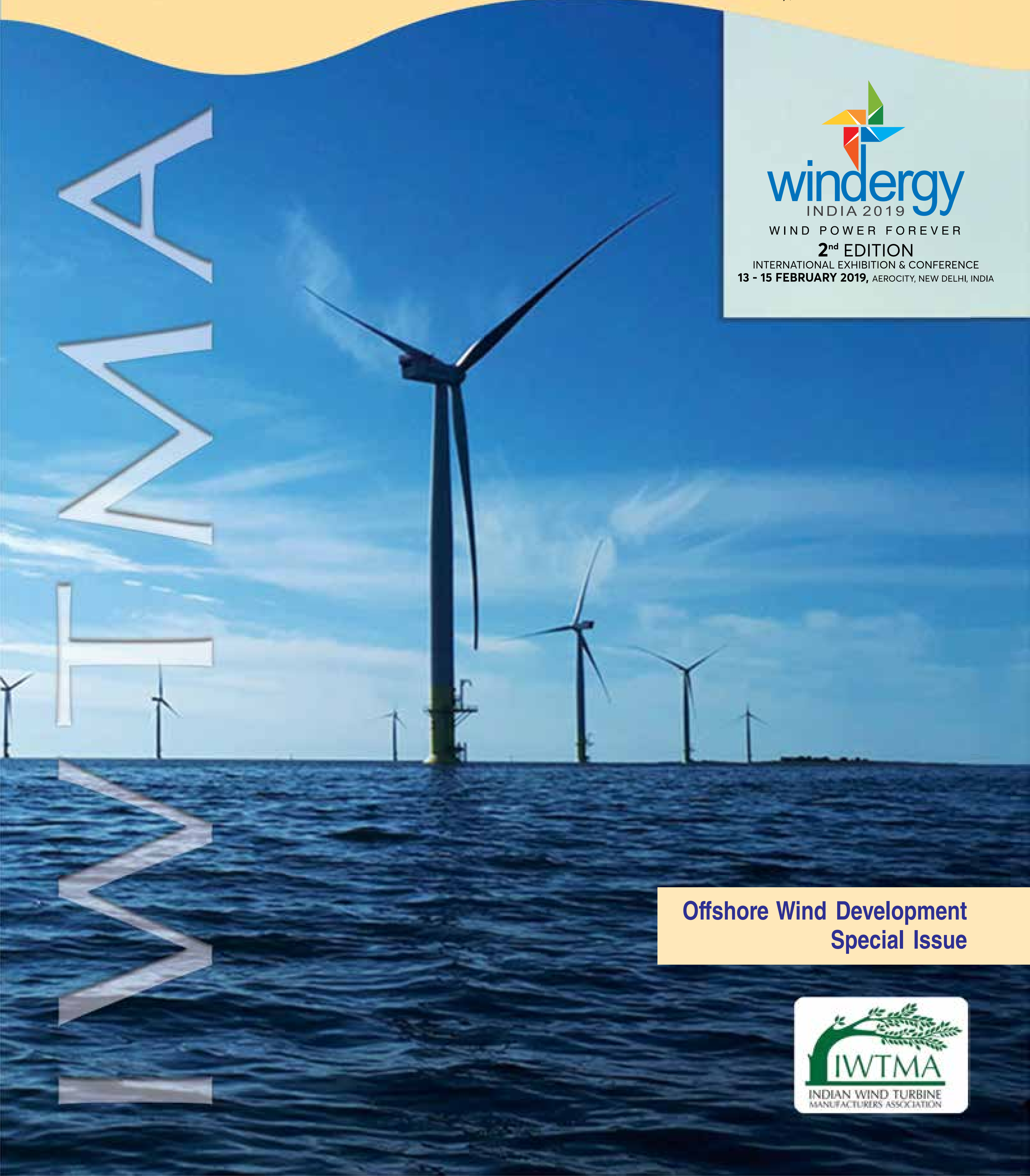
Indian Wind Power

Volume: 4 Issue: 2 June - July 2018 ₹ 10/-
Bimonthly, Chennai



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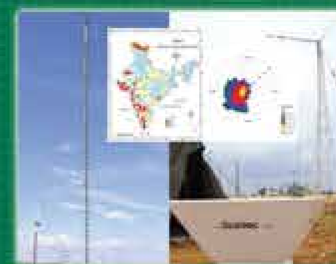

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An Autonomous Research & Development Institution under the Ministry of New and Renewable Energy, Government of India

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

A Bi-monthly Magazine of Indian Wind Turbine Manufacturers Association

Volume: 4 Issue: 2 June - July 2018

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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

(For Internal Circulation only)

From the Desk of the Chairman - IWTMA

Dear Readers,

Greetings from IWTMA!

India has embarked upon the journey of largest renewable energy capacity expansion programme in the world. Ministry of New and Renewable Energy (MNRE) has recently increased the renewable energy target to 227 GW by 2022 from 175 GW earlier. This also includes increase in wind target from 60 GW to 67 GW. With over 34 GW installations, wind energy has played a significant role in enabling India's transition to a low carbon economy, job creation and boosting exports. We are confident, wind energy will continue to be the catalyst in government's "Make in India" vision and provide sustainable and affordable energy to all.

The first quarter of the Financial Year 2018-19 (FY19) has concluded and it signals momentum in the wind sector. The sector is at an inflection point as exponential volume growth beckons. There is a healthy order pipeline, owing to SECI auctions and state level bids. We are seeing large scale projects of 200 to 300 MW capacities, which provide economies of scale. Apart from onshore wind, several emerging opportunities such as repowering, off-shore wind and wind-solar hybrid are witnessing positive policy actions from the government. There is immense potential in each of these areas waiting to be unlocked. Ministry of New and Renewable Energy has already announced policies on Repowering, Wind-Solar Hybrid and Offshore Wind. On offshore, Government has invited Expression of Interest for 1 GW and has announced an ambitious target of 5 GW by 2022 and 30 GW by 2030.

The Indian wind sector is committed to create additional 2 million jobs, broaden the vendor base which is over 4000 vendors now and promote domestic investment with a level playing field to the MSME industries. The Government is already taking steps in this direction.

Aligned to the momentum in offshore wind energy in India, the theme of the current edition is "Offshore Wind Development". Our readers will get in-depth insights on this subject through the series of articles from sector experts.

I am also pleased to announce the next edition of "Windergy India 2019" on 13th, 14th and 15th February 2019 at Aerocity, New Delhi. Apart from showcasing world-class turbines and technologies, it will also be a thought leadership platform for everything related to the wind energy sector – from technical conferences, panel discussions with national and international speakers. We look forward to welcome you at Windergy India 2019.

Tulsi Tanti
Chairman

Global Offshore Wind Update

Global offshore wind market scores all-time high market up 95%

Steve Sawyer
Secretary General

Lauha Fried
Communications Director

Liming Qiao
China Director

Global Wind Energy Council, Brussels, Belgium

"Wind power is leading the charge in the transition away from fossil fuels; and continues to blow away the competition on price, performance and reliability", said Steve Sawyer, GWEC Secretary General. "Both onshore and offshore, wind power is the key to defining a sustainable energy future".

The Global Wind Energy Council (GWEC) released its ***Global Wind Report*** in the end of April, showing a maturing industry successfully competing in the marketplace, even against heavily subsidized traditional power generation technologies. More than 52GW of clean, emissions-free wind power was added in 2017, bringing total installations to 539 GW globally. With new records set in Europe, India and in the offshore sector, annual markets will resume rapid growth after 2018.

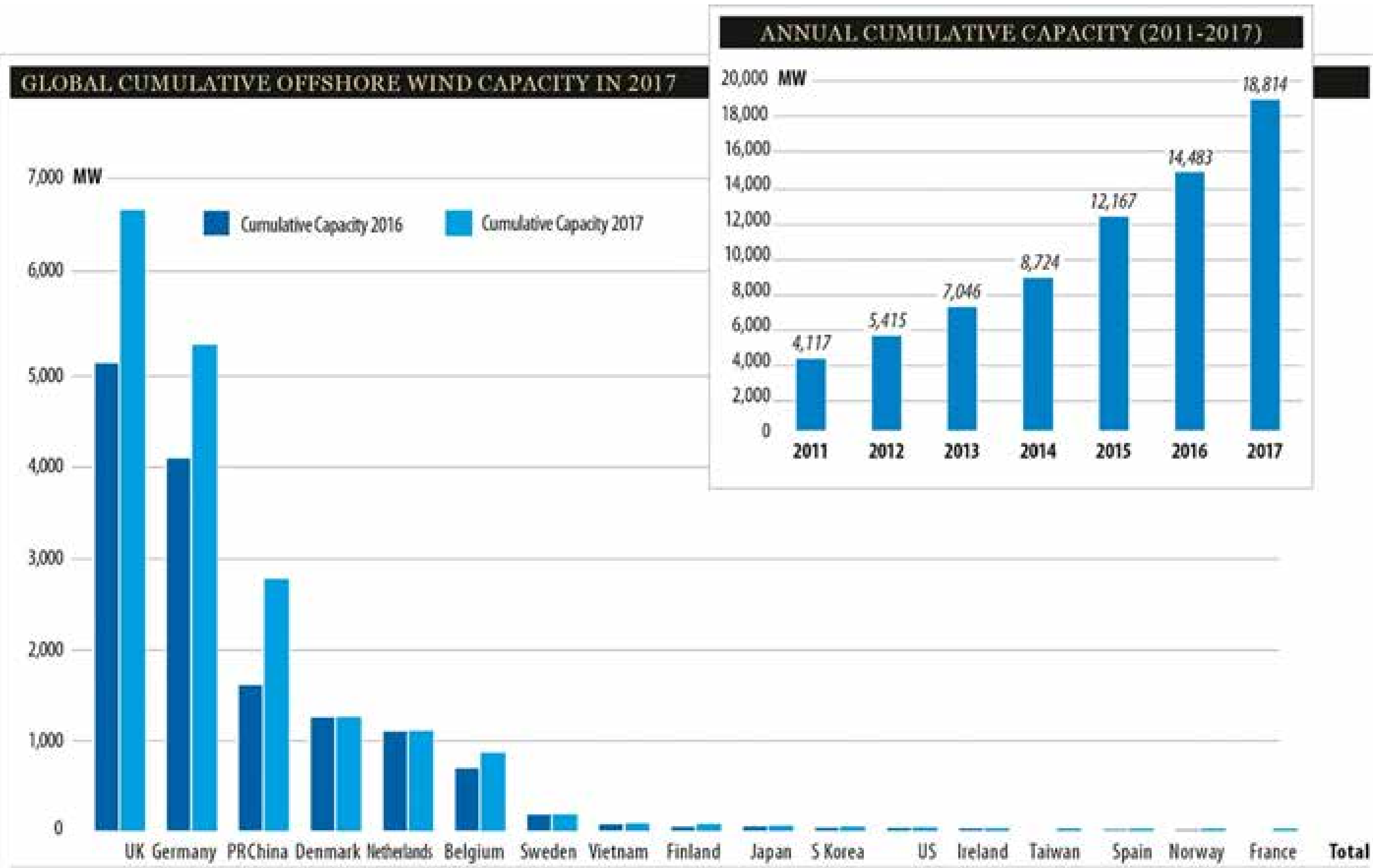
2017 was a spectacular year for the offshore wind sector: the cratering prices with first zero bids for offshore in Germany; and a full 'zero subsidy' tender in the Netherlands; larger and larger turbines whose size boggles the mind; a plan for building an offshore wind island with more than twice today's total installed offshore wind power in Europe; and the number of markets expanding rapidly – including newcomers from Australia, Brazil and Turkey. The rapid maturing of the technology has meant that offshore wind is taking shape as a mainstream energy source.

A historical record of 4,331MW of new offshore wind power was installed across nine markets globally in 2017. This represents an increase of 95% on the 2016 market. Overall, there are now 18,814MW of installed offshore wind capacity in 17 markets around the world.

At the end of 2017, nearly 84% (15,780MW) of all offshore installations were located in the waters off the coast of eleven European countries. The remaining 16% is located largely in China, followed by Vietnam, Japan, South Korea, the United States and Taiwan.

The UK is the world's largest offshore wind market and accounts for just over 36% of installed capacity, followed by Germany in the second spot with 28.5%. China comes third in the global offshore rankings with just under 15%. Denmark now accounts for 6.8%, the Netherlands 5.9%, Belgium 4.7% and Sweden 1.1%. Other markets including Vietnam, Finland, Japan, South Korea, the US, Ireland, Taiwan, Spain, Norway and France make up the balance of the market.

The spread of the offshore industry beyond its northern European home to North America, East Asia, India and elsewhere has begun. The first US offshore wind farm came online in 2016, China's offshore wind industry has finally taken off, and Taiwan has an ambitious programme lined up. The number of countries planning pilot projects or full-scale development of commercial-scale offshore wind farms is rapidly growing; the latest newcomers wanting to enter the sector are in Australia, Brazil and Turkey.



	UK	Germany	PRChina	Denmark	Netherlands	Belgium	Sweden	Vietnam	Finland	Japan	S Korea	US	Ireland	Taiwan	Spain	Norway	France	Total
Total 2016	5,156	4,108	1,627	1,271	1,118	712	202	99	32	60	35	30	25	0	5	2	0	14,483
New 2017	1,680	1,247	1,161	0	0	165	0	0	60	5	3	0	0	8	0	0	2	4,331
Total 2017	6,836	5,355	2,788	1,271	1,118	877	202	99	92	65	38	30	25	8	5	2	2	18,814

Source: GWEC

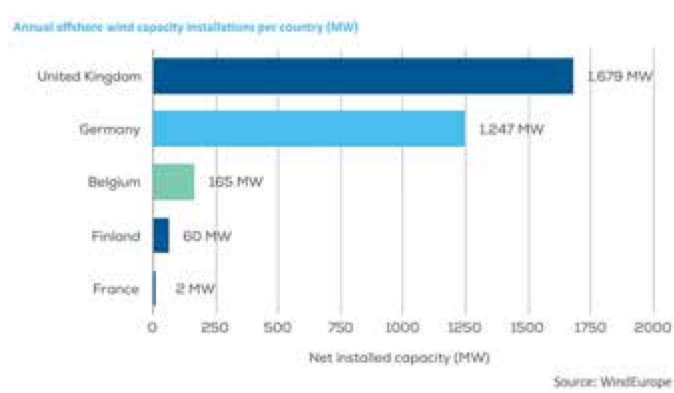
Meanwhile, offshore wind had its first 'subsidy-free' bids for offshore projects in Germany and an entire subsidy free tender in the Netherlands, with winners of new offshore capacity receiving no more than the wholesale price of electricity. Overall, offshore prices for projects to be completed in the next 5 years or so are half of what they were for the last five years; and this trend is likely to continue.

The reasons for this are many: the maturing of the industry, the improvement and maturation of the technology and management thereof, growing investor confidence, and the introduction and deployment of a new generation of turbines, with enormous swept area and tremendous output.

Record Year for European Offshore Wind

The European offshore wind industry had an all-time record year adding 3,148 MW in 2017, corresponding to 560 new offshore wind turbines across 17 wind farms. This is double the size of the 2016 market and represents a 13% increase on the previous record set in 2015. During 2017, fourteen projects came online, including Europe's first floating offshore wind farm. 2017 also saw Final Investment Decision (FID) on six new offshore wind projects to be installed in the coming years. The new investments total €7.5bn and cover 2.5 GW of capacity.

Just over half of all capacity (53%) brought online in 2017 was in the United Kingdom, including the commissioning of the first floating offshore wind farm: Hywind, in Scotland. The second largest market was Germany with 40% of overall European capacity, largely realised through the commissioning of the Veja Mate and Wikinger projects. Belgium represented 5% of the total share and Finland commissioned its first offshore wind farm specifically designed for icy conditions at Pori Tahkuoloto 2. Moreover, France's first offshore wind turbine, the 2 MW



Floatgen demonstrator came online. In Denmark, 5 MW were decommissioned at Vindeby. Overall in 2017, work was carried out across 26 wind farms including grid connections, wind turbine erections and foundations installed.

In cumulative terms, Europe now has a total installed offshore wind capacity of 15,780 MW. This corresponds to 4,149 grid-connected wind turbines across eleven countries.

The UK has the largest offshore wind capacity in Europe, with 6,836 MW, followed by Germany (5,355MW) and Denmark (1,271MW). The Netherlands is in fourth place with 1,118MW, and Belgium fifth with 877MW. Combined, the top five EU countries represent 98% of all grid-connected offshore wind installations in Europe.

Installations in the North Sea account for 71% of all offshore wind capacity in Europe. The Irish Sea has 16% of installed capacity, followed by the Baltic Sea with 12% and the Atlantic Ocean 1.2%.

China's Offshore Finally Taking Off

With all the focus on the dramatic success in the offshore sector in Europe, it's worth noting that China's offshore industry is finally taking off. 1,161 MW of new installations in 2017 brought the cumulative total to 2,788, putting China in third place globally, behind the UK and Germany.

The new installations in 2017 are spread across 18 offshore wind farms, and nine of them (totalling 968 MW) are in Jiangsu Province, which continues to be the major focus of offshore development. There were four projects totalling 65 MW in Fijian Province, and the remaining five were spread across Guangdong, Zhejiang and Hebei Provinces. The market leaders in terms of turbines were Shanghai Electric (50%), followed by Goldwind (18%), Envision (17%) and CSIC (9%).

Unlike China's onshore targets, which have been regularly exceeded, we have come to expect the offshore targets not to be met, especially the very ambitious ones set nearly a decade ago. Now, however, it seems the industry is on track and it will easily meet the national 2020 target of 5 GW, probably well ahead of time.

Japan Installs another Floater in 2017

Despite Japan's favourable conditions and abundant offshore wind potential, the sector has developed at a slow pace. Japan added 5MW in 2017, which brought the country's total installations to 65MW, spread over 29 turbines and 11 projects. Japan has been experimenting with both fixed and floating foundations, with the floating installations accounting for 16MW in two projects.

A feed-in tariff for offshore wind has been set at JPY 36/kWh. However, the Japanese Ministry of Economy, Trade and Industry (METI) has proposed moving to a new system of auctions for fixed foundation offshore wind. The current level of FIT will be maintained for floating projects up until a total of 820MW, after which the auction system will be applied for all projects.

The next floating turbine is expected to come online during summer 2018 at Kitakyushu as NEDO's (New Energy and Industrial Technology Development Organization) new national project. The 3.5MW two bladed turbine is designed by Germany's Aerodyn, using a moon-pool type concept from France's IDEOL.

There are a further 12GW of offshore wind projects currently under various stages of development, of which 22 projects totalling 5,079MW are at an advanced stage. The remaining 7GW of projects are at pre-EIA (environmental assessment) stage and waiting for a 'proposal rush' for a transmission auction which will be organised by Tohoku Electric Power Co. The first commercial project is expected to start operation in 2021. Japan's wind industry has a target to reach 10GW of offshore wind by 2030.

Taiwan's Ambitious Target Set at 5.5GW by 2025

Taiwan has become one of the offshore wind power hotspots in Asia. International offshore developers and OEMs are attracted by the government's generous offshore wind feed-in tariff and strong wind resources, as well as the government's ambitious targets and policy to promote the clean energy industry.

Taiwan's initial offshore wind target of 3 GW by 2025 was quickly exceeded by over-subscription of projects proposed by developers, which led to an upward adjustment of the target in 2017 to 5.5 GW by 2025. The target of 520MW by 2020 was maintained while the target for 2030 was raised to 10-17GW.

Taiwan's major development hotspot is located off Changhua county, where the 128MW Formosa project can also be found. There is a great deal of activity laying the ground work for the future development and nearby Taichuang Harbour is becoming a main port to provide support for offshore development. Taipower has signed a deal to build what it says will be Southeast Asia's largest offshore wind port facility in Taichung. State-controlled Taipower will invest about $100m in the facility in a link up with Taiwan International Ports, according to the Taiwanese government, which is pursuing an ambitious offshore wind expansion programme. Siemens Gamesa has also signed an MOU to set up an offshore wind supply chain at the Taichuang Harbour.

South Korea Readies for Offshore Wind Expansion

South Korea aims to triple the share of renewables in the country's power mix by 2030 which translates to adding about 47GW of new wind and solar capacity, according to the government's latest draft policy roadmap.

The East Asian nation will also cut back the shares of coal and nuclear in its electricity supply – although not as sharply as expected – under the Ministry of Trade, Industry and Energy's (MOTIE) draft of the ***Eighth Basic Plan for Electricity Supply and Demand***, which provides Korea's power development roadmap for the next 15 years.

According to the plan, renewables will account for 27.3% of Korea's total power capacity in 2030, increasing more than threefold from 9.7% this year. The share of renewables in power generation will increase accordingly from 6.2% now to 20% in 2030.

Although, the draft does not mention specific sector targets, analysts have estimated that South Korea will be looking to reach 5GW of onshore wind by that date, about five times the total in place now, and balloon its offshore base to 13GW from a negligible level now.

The surge of renewable energy will help South Korea to cut 237 million tons of GHG emission and limit particulate pollution, according to the roadmap.

US Offshore Development Led by New York

While there were no new offshore installations in the US in 2017, a lot of activity took place, laying the ground ensuring solid development for the next few years. There are ambitious plans at the state level up and down the East Coast, and great interest from European manufacturers, developers and investors in this potentially huge new market segment.

By the time of writing this report, GE announced the world's first 'double-digit' turbine, the Haliade-X 12MW. Other manufacturers are expected to follow soon to develop this next generation of huge offshore turbines.

In terms of the development plan, the north-eastern states are still the hotspot of offshore wind development in the US. The high wholesale electricity price, high electricity demand along with the state governments backing for the renewable energy industry are the main drivers of offshore wind development. The states on the forefront of offshore wind power development are Rhode Island, New York, New Jersey and Massachusetts.

New York State has become the new climate leader in US, after California, with a series of government measures and targets being introduced to boost the clean energy industry. An offshore wind target has been set at 2.4GW by 2030. In January 2018, New York State also released its long-awaited ***Offshore Wind Master Plan***, encompassing 20 in-depth studies on a variety factors that will affect the state's ability to reach its 2.4GW offshore wind target by 2030.

Rhode Island was home to the first US offshore wind site, the 30MW Block Island project which was completed in 2016. The

state now plans to issue a request for proposals (RFP) for up to 400MW of renewable energy, including offshore wind, in the course of 2018. Rhode Island has a target to reach 1GW of renewable energy by the end of 2020.

However, offshore wind development is not only limited to the North East. In March, Avangrid won North Carolina's offshore lease auction, and there is great industry enthusiasm under the new administration which has promised a lighter regulatory process and faster project timelines to boost the offshore wind sector.

Upcoming Markets

India Prepares for its First Demonstration Projects

The GWEC-led FOWIND[1] (Facilitating Offshore Wind in India) project prepared a roadmap for offshore wind power in India. The project focused on assessing the two key coastal states of Gujarat and Tamil Nadu. As a part of the project a LiDAR unit was deployed off Gujarat in the Gulf of Khambat at the beginning of November 2017. These first offshore measurements will be critical for the future of the sector. Further, Fowind's pioneering efforts have paved the way for another private LiDAR unit to be deployed in the Gulf of Kutch (also Gujarat) and India's National Institute for Wind Energy (NIWE) plans to deploy a LiDAR in the most promising zone in Tamil Nadu later in 2018. Offshore wind resource assessment is underway, and will need to verify the current estimates of about 35 GW of potential off Gujarat and around 30 GW off Tamil Nadu.

It appears that the next steps going forward will be:

– A call for OEMS to contribute to NIWE's 'test field' which will be established in Tamil Nadu on a spit of land that sticks out into some of the best offshore wind in India at Dhanushkodi. This is envisaged to be a demonstration facility along the lines of the Danish site at ***Østerild***, and will coincide with NIWE's placement of a LiDAR in the same region.

– Autumn of 2018 – a request for proposals for a demonstration project of somewhere between 500 and 1000 MW in the Gulf of Khambat in Gujarat. It is expected that a feed-in tariff/PPA structure will be utilised for this project, although it is not known what the level will be.

– Autumn of 2019 – a request for proposals for a demonstration project of between 500 and 1000 MW off Tamil Nadu in the Gulf of Mannar (south of Dhanushkodi) in our Zone A.

If this all moves forward, then we will be looking at tendering for offshore projects in the year or two following this.

India has the world's 4th largest onshore wind market with a total installed capacity of over 34 GW. However, India has an acute need for large-scale, clean and indigenous energy generation to fuel its rapidly growing economy. Offshore wind power could play a very important role in India due to the large wind resources available near centres of high-energy demand.

Vietnam Takes Steps Forward

Vietnam's first near-shore/intertidal wind project, the 99.2MW Bac Lieu wind farm, is the first offshore wind farm ***in the Mekong Delta region, and came online in stages from 2013-2015.*** Another near-shore wind project, the 800MW Phu Cuong wind farm, also located in Mekong Delta, is now gearing up. The first phase, the Phu Cuong 1 Wind Farm (170 MW), is expected to reach financial close in 2018.

In 2016, new projects, both onshore and offshore, are being developed in Soc Trang Province, which is emerging as the next hot spot for wind development in Vietnam.

Despite slow progress to date, the Vietnamese wind market has started attracting world leading turbine manufacturers and investors. Vietnam may become the next Gigawatt sized wind market in Asia, once the regulatory and financial conditions are corrected, which may come during the course of 2018.

[1] www.fowind.in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Offshore Wind Energy in India


Dr. Rajesh Katyal
Deputy Director General

Dr. K. Balaraman
Director General

National Institute of Wind Energy (NIWE), Chennai

Introduction

India has about 34 GW onshore wind installation. Onshore wind installations in India are a success story with over 34 GW wind turbine installations by March 2018. However, there is a huge potential for deploying wind turbines deep into the sea, called as offshore wind farming. Surface of seas and lakes are generally smooth, as such the roughness of seascape is very low. The temperature variations above the surface of sea are much smaller than above land. Thus the winds available on the sea are generally higher (as shown in Figure 1 below), less turbulent and possess higher density when compared to land (typical values are about 10-12% above sea). The wind turbines located at sea are therefore expected to have higher generation leading to higher capacity factor and longer life.

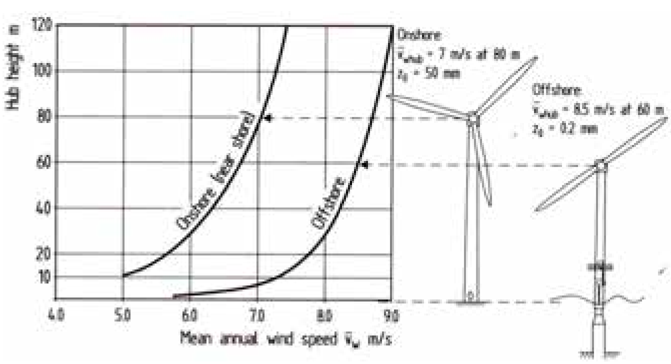


Figure 1: Logarithmic Wind Profile for Onshore and Offshore Wind Turbines

In recent years, the offshore wind industry has grown beyond Europe to North America and East Asia, and the future of the sector looks promising. The total offshore installation across the world is 18,814 MW with UK leading with total installed capacity of 6836 MW followed by Germany and China at 5355 MW and 2788 MW respectively. India is blessed with a coastline of 7600 km surrounded by water on three sides and has bright prospects of harnessing offshore wind energy. The Preliminary assessment along the Indian coastline through met mast measurements and satellite data assessment show reasonable potential. The Government of India notified the National Offshore Wind Energy Policy in October 2015 to provide a policy framework for the exploitation of offshore wind energy and National Institute of Wind Energy (NIWE) has been identified as the nodal agency for development of offshore wind energy in the country. Since the assessment of potential along offshore has mainly relied on modeled wind data based on onshore wind measurements and satellite data, there is a need to validate this with real time measurements. The present focus of NIWE is to carry out offshore wind resource assessment studies off Gujarat and Tamil Nadu coasts in zones identified through desktop studies.

Efforts by NIWE

The Ministry of New and Renewable Energy (MNRE), Government of India has made consistent efforts to create a conducive environment for the development of offshore wind in the country. During the preparation of the Indian Wind Atlas, RISO DTU Denmark, along with NIWE indicated some offshore wind potential in the eastern shore compared to the western shore of South India. A preliminary estimation of the offshore potential was carried out by Scottish Development International

Figure 2: Coastal Mast Location
Offshore Wind Resource Assessment – A First Step

(SDI) and NIWE for Tamil Nadu region in 2010. Under National Wind Monitoring Programme wind has been measured at 74 locations in the coast line by NIWE as shown in Figure 2. Preliminary estimates have shown modest potential along western and eastern coast line while the East coast is prone to cyclone.

As a first step NIWE has installed a 100 meter met mast at the Southern tip of Dhanushkodi to validate the offshore wind potential estimates and the measurements were commenced in October 2013. The site is situated on the shoreline which is a narrow piece of land jutting towards Sri Lanka and surrounded by water in three directions, as shown in Figures 3a and 3b.

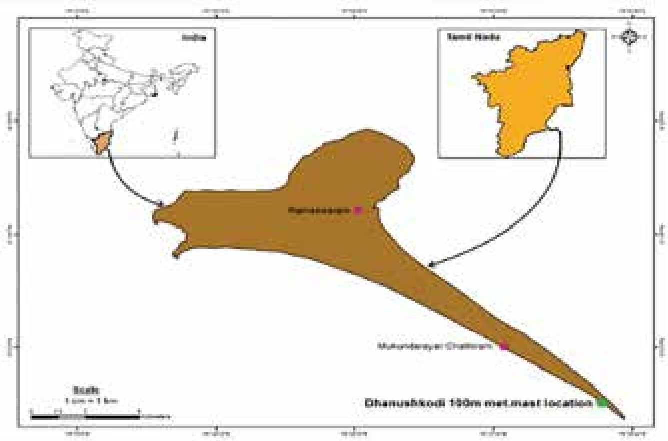


Figure 3a: Location Map of 100 Meter Mast

Figure 3b: Satellite Image of Mast Location

The results reveal that the location has promising offshore wind potential. The monthly average wind speed at 102 m is seen to vary between 5.51 m/s to 10.24 m/s with an annual average wind speed of 8.65 m/s. Figure 4 shows the monthly profile of wind speed measured at Dhanushkodi.

Offshore Wind Resource Assessment at Gulf of Khambhat

The preliminary resource assessment carried out using model studies by various organizations indicates that there is

Figure 4: Monthly Profile of Wind Speed Measured at Dhanushkodi

good potential in the Gulf of Khambhat in Gujarat and Gulf of Mannar in Tamil Nadu. The FOWIND (Facilitating Offshore Wind in India) consortium, with NIWE as a knowledge partner carried out prefeasibility studies and demarcated eight offshore zones each in the states of Gujarat and Tamil Nadu, as given in Figures 5 & 6 below.

Figure 5: Eight Identified Zones in Gujarat

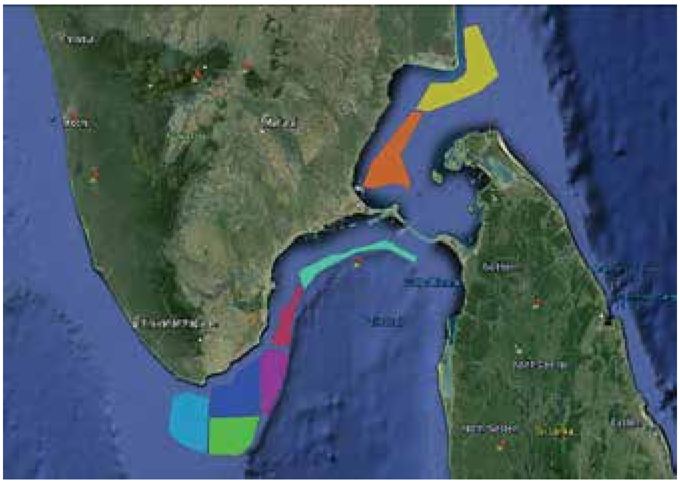


Figure 6: Eight Identified Zones in Tamil Nadu

In order to validate the potential at the zones demarcated under FOWIND project, NIWE along with the support of ESSO-NIOT prepared a detailed project report for establishment of

LiDAR-based offshore wind measurement platform off Pipavav in Gulf of Khambhat, Gujarat Coast at one of the First Offshore Wind Project of India (FOWPI).

COWI India, a consortium partner of First Offshore Wind Project of India (FOWPI) has developed a met ocean model for the preliminary implementation of first off-shore wind farm project of India, on a seabed area of 70 sq. km. with a tentative capacity sizing of 200MW near the Gulf of Khambhat (Figure 7) with active technical support from NIWE.

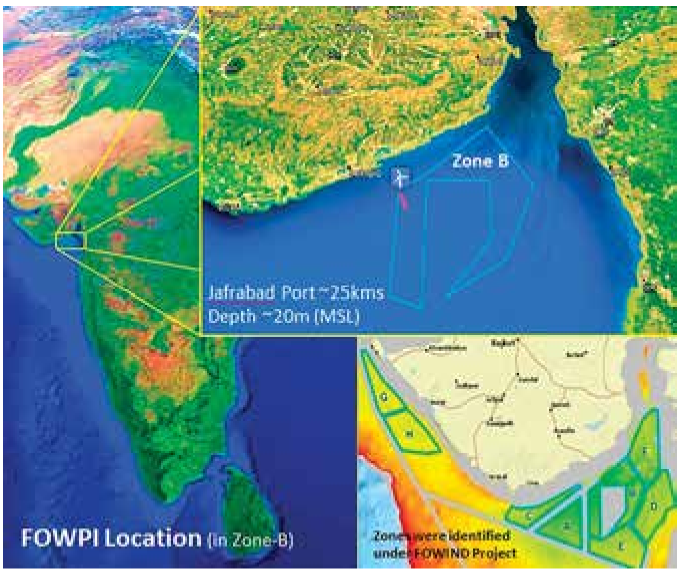


Figure 7: Location identified for the First Offshore Wind Farm

In order to update this preliminary met ocean study report to a technical level usable for detailed design of foundations and WTG, a series of on-site measurements (monsoon and outside the monsoon season) of environmental data are needed. The measured data shall be used for validating the site-specific met-ocean conditions predicted by the numerical models at the actual wind farm site.

Geophysical and Geotechnical Investigations

Geophysical Studies

Other than this, NIWE has initiated the works of geophysical and geotechnical investigations or a 250 square Kilometre area at Gulf of Mannar, Tamil Nadu and 140 square Kilometer area at Gulf of Khambhat, Gujarat as shown in Figure 8 below. Geophysical surveys in offshore wind farm location will give information about the following:

- Bathymetry (Water Depth & Seabed mapping)
- Seabed topography
- Nature of seabed sediments
- Seismic profile (Seabed & Geological profile)
- Magnetic anomalies
- Seabed & Sub-seabed hazard, if any.

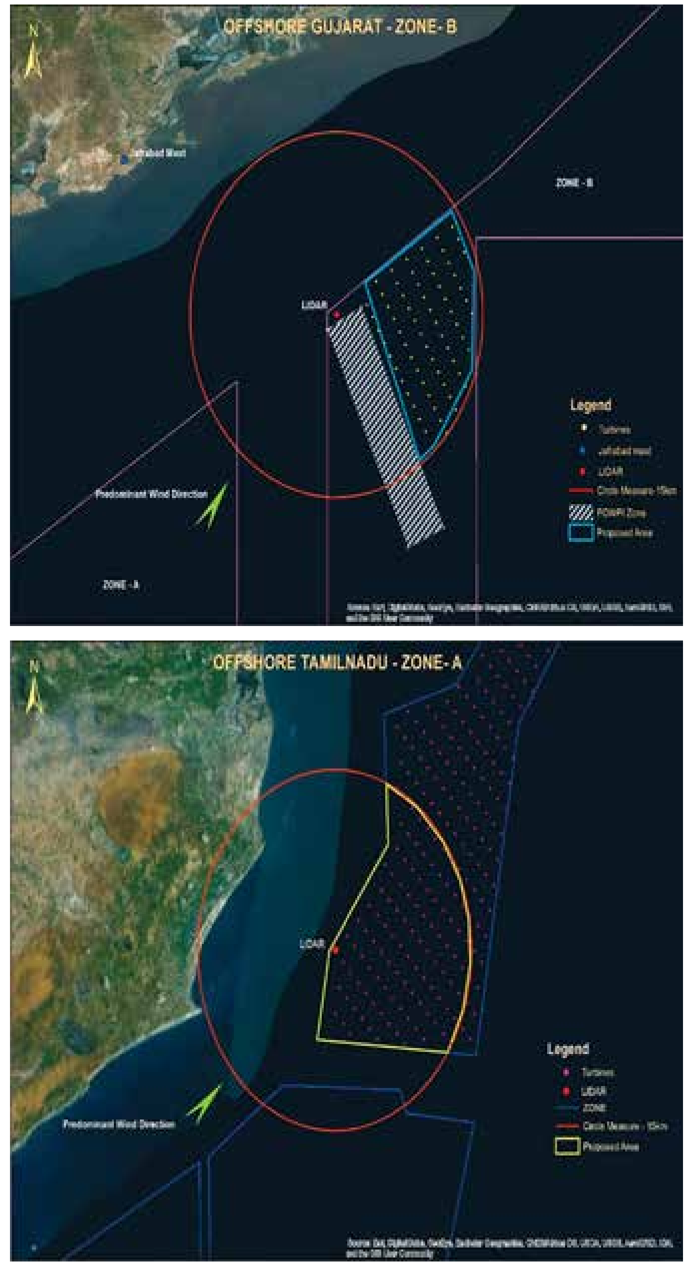


Figure 8: Geophysical Survey Area - Gujarat and Tamil Nadu

The Representative images of the geophysical survey outputs are shown in Figure 9 below.

Geotechnical Investigations

After completion of geophysical studies, location for Geotechnical borehole studies will be decided. Information about the soil characteristics will act as a useful pointer in deciding the type of foundation and design of foundation structures. A schematic view of the offshore geotechnical investigations are shown in image below.

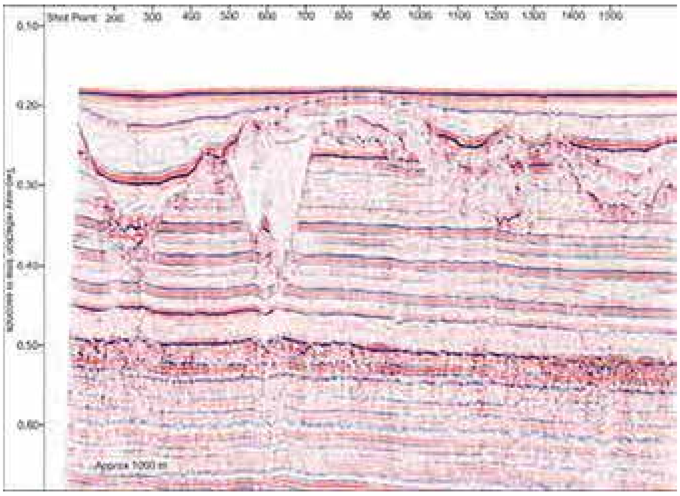


Figure 9: Sub Bottom Profiler

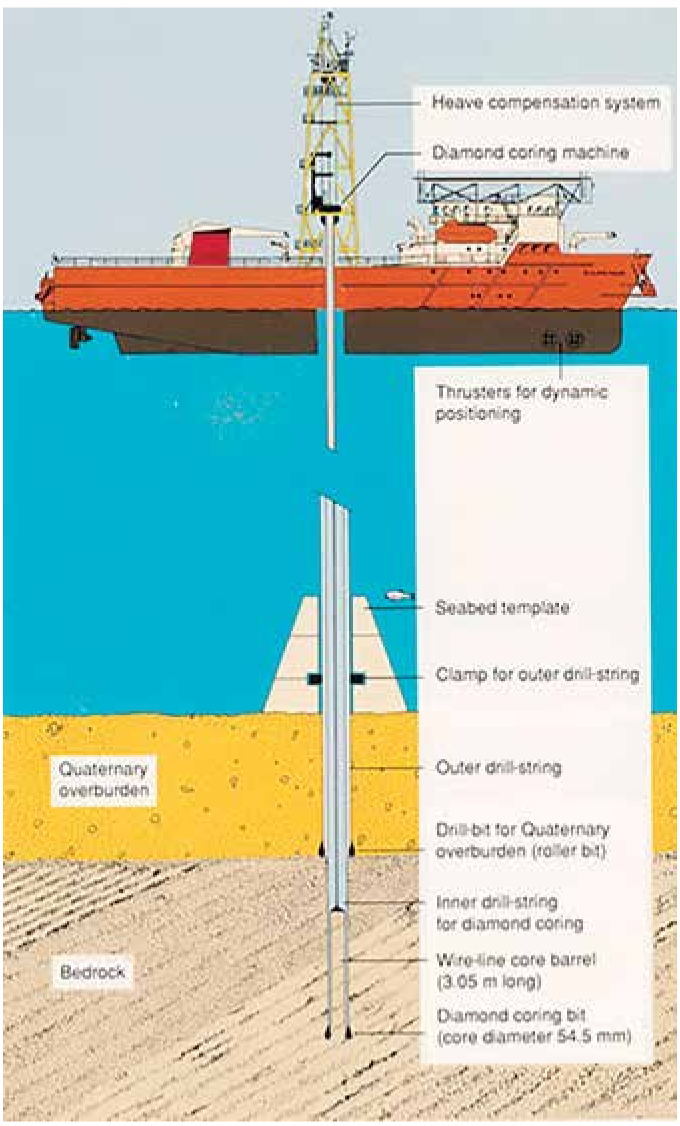


Figure 10: Schematic Geotechnical Investigations

Way Forward

The Preliminary studies of offshore wind resource along the Indian coastline based on satellite data assessment and near shore, measurements have shown good potential along the Tamil Nadu and Gujarat coasts. These needs to be rechecked/ validated by fresh long-term on-site measurements for better understanding the wind resource availability in order to take informed decisions. Also, studies on oceanographic parameters such as wave, tide and current will be initiated near LiDAR locations. These will help in designing of offshore wind turbine suitable for Indian conditions.

In order to carry forward the offshore wind generation NIWE is carrying out studies and surveys for demarcation of potential zones as per the notified offshore wind energy policy with installation of 3 LiDAR-based wind monitoring station in both Gujarat and Tamil Nadu coast is also planned.

Snippets on Wind Power

45 Lakhs Jobs could be Created in Renewable Energy Sector over 25 years

India's renewable energy sector, including the solar and wind power generation segments, could create new job opportunities between 20 to 45 Lakhs over the next 25 years, according to a new detailed study of the country's energy sector. Also, the two green energy sectors are now outpacing fossil fuel energy as investment opportunities providing 12 per cent higher annual returns, 20 per cent lower annual volatility and 61 per cent higher risk-adjusted returns than the coal and natural gas sectors, the study conducted by Climate Policy Initiative and Indian School of Business along with experts from Jawaharlal Nehru University (JNU) and Indian Institute of Technology (IIT)-Delhi has found. The study also found that higher renewable energy generation corresponds to lower unemployment, fewer net energy imports, lower fiscal deficit and higher GDP.

India's Spot Power Price Rockets to 5-Year High of ₹ 11.41 Per Unit

Spot power price touched 5-year high of ₹ 11.41 per unit at IEX on 22nd May 2018, which experts attributed to aggressive bidding by captive units following government's decision to ramp up coal supplies to power plants.

FOWIND (Facilitating Offshore Wind in India) Project

Steve Sawyer, Secretary General
Global Wind Energy Council, Brussels, Belgium

The 51-month FOWIND (Facilitating Offshore Wind in India) project, financed largely by the European Union (with supporting contributions from the Gujarat Power Corporation Ltd and Renew Power), finished up with a workshop in Delhi in early March 2018. Focused on developing a roadmap for the development of offshore wind in the states of Gujarat and Tamil Nadu, the project was executed by Global Wind Energy Council (GWEC) along with partners DNV-GL, the Center for Science, Technology & Policy, and World Institute of Sustainable Energy (WISE); supported by the National Institute for Wind Energy (NIWE) and in close cooperation with the Ministry of New and Renewable Energy (MNRE).

Five years ago, when we were preparing our proposal for this project, the general reaction from people when asking about offshore wind in India was "What? India? You've got to be kidding". However, in the intervening period much has changed, both in India and globally.

The European offshore sector set itself the target of getting prices below €100/MWh by the end of the decade, and through hard work and closer cooperation between the public and private sectors, this target was achieved well ahead of time, and the spectacular price drops in the offshore sector in the past few years mean that it is now a competitive source of power…in Europe.

Elsewhere, the Chinese market has finally broken through, installing 1.1 GW in 2017. Taiwan has an ambitious build-out plan for over 5 GW which is now being implemented rapidly; Japan is moving forward with its first commercial scale facility… we have breakthrough first projects in both the US and South Korea, and the first ***floating*** offshore wind farm in Scotland. In addition to the interest in India, we now have active pursuit of offshore projects in Australia and Brazil. However, in all of these new markets, the starting prices are very high, although we're already seeing signs of rapid price reduction in the US market, due to the substantial pipeline up and down the US east coast.

The appetite for offshore in India has grown large indeed, in line with the government's very ambitious plans for renewable energy. The process for procuring the initial projects is now underway, with a call for expressions of interest in developing up to 1000 MW of offshore wind off Gujarat. The call has received a lot of attention, including expressions of interest from most of the major international developers and OEMs, as well as a healthy selection of national developers.

The FOWIND project has laid down a solid foundation for this development. Beginning with our survey of international policy and best practice, this was followed up by pre-feasibility studies for wind farms in Gujarat and Tamil Nadu. Studies on supply chain, ports and infrastructure for both states followed, as well a look at grid integration challenges. Finally, in December of last year we published our roadmap to 2030, followed by the full feasibility reports for the two states which were released in our concluding event in Delhi.

FOWIND has provided a roadmap for initiating a sustainable and commercially viable offshore wind industry, focusing on two out of a total of eight coastal states and the Union Territory of Goa. Further, technical investigations could deliver a more detailed pan-India outlook for offshore wind developments over the longer term.

All FOWIND reports are available at "http://gwec.net/publications/topical-report/".

The project also involved workshops, study tours, press events and 'selling' the idea of India offshore around the world, but the most challenging part of the project was procuring and deploying a LiDAR unit off the coast of Gujarat to get the first real measurements of the offshore resource. As with any 'first' there were unforeseen delays and complications due to customs tariffs, permitting, site selection, platform construction and dealing with unexpected bottom soil conditions, but we finally got the machine deployed and collecting data as of the end of October of last year. The information will be invaluable to informing the programme going forward; and will hopefully pave the way such that subsequent deployments will be easier and smoother.

Our concluding workshop was billed as a 'One-Day Industry Conclave' and was held in Delhi's 'The Claridges' hotel. The event was packed, with more than 75 attendees. As well as

Welcome to Mr. Ben Backwell CEO, GWEC

The Global Wind Energy Council (GWEC), the trade association representing the global wind sector, has appointed Ben Backwell as its new Chief Executive Officer (CEO). He replaces Steve Sawyer, who joined GWEC as its first Secretary General in 2007. Sawyer will continue his work with GWEC as its Senior Policy Advisor.

GWEC GLOBAL WIND ENERGY COUNCIL

Indian Wind Turbine Manufacturers Association (IWTMA) is a founder member of GWEC and welcomes Mr. Ben Backwell.

Ben Backwell joins GWEC from global advisory company FTI Consulting, where he was a Managing Director in its Clean Energy Practice. Backwell is a leading strategist in the renewable energy industry and has advised many of the leading technology companies, utilities, developers and IPPs and financial institutions active in the sector. He is a former journalist and analyst who has covered energy policy and markets in a number of geographies including Europe, the US and Latin America.

presenting the final Feasibility Reports for the project, the event featured interventions from Counsellor Tania Friederichs, Head of Research & Innovation Sector at Delegation of the European Union to India, and from MNRE Joint Secretary Mr. B.P. Yadav. Five years ago, you couldn't have gotten 75 people in a room to talk about offshore in India…at the March workshop we could have doubled that number with ease. But there is still a lot of work to do.

India has the world's 4th largest onshore wind market with a total installed capacity of more than 34 GW. However, India has an acute need for large-scale, clean and indigenous power generation to fuel its rapidly growing economy. Offshore wind power could play a very important role in India due to the large wind resources available near demand centers. With the right policies and careful planning India could build a sustainable offshore industry for the future, and we are proud that the FOWIND project has been to help it off to a good start.

Snippets on Wind Power

Windergy India 2019 Announced

Indian Wind Turbine Manufacturers Association has announced conducting of Windergy India 2019, 2nd Edition International Exhibition and Conference from 13th to 15th February 2019 at Aero City, New Delhi, India.

APPC for 2018-19 Determined as Rs. 3.53/kWh

Based on the tariff orders issued by the SERCs/JERCs for FY 2017-18, the APPC at the National level has been determined as Rs. 3.53/kWh. This APPC shall be applicable during FY 2018-19.

Largest Offshore Wind Turbine from GE

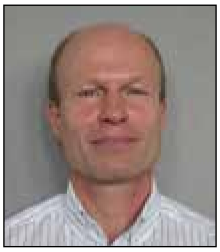
GE has developed the largest and most powerful wind turbine: the Halidade-X, a 12 MW direct drive generator with an industry leading gross capacity factor of 63 percent and advanced digital capabilities. Haliade-X will produce 45 percent more energy than any other offshore turbine available today. Towering 260 meters over the sea, the Haliade-X 12 MW carries a 220-meter rotor, the 107-meter-long blades, the longest offshore blades to date. It will generate up to 67 GWh power annually, enough clean power for up to 16,000 households per turbine, and up to 1 million European households in a 750 MW windfarm configuration.


ReGen
POWERTECH
Introducing
the new ReGen make
"WD 121, 2.8 MW"
wind generator platform with a rotor diameter of 121m. The evolution of our highly successful 1.5 MW and 2 MW wind platforms, the new WD 121 2.8 MW IEC IIIB provides unparalleled performance at high efficiencies even in low and medium wind sites.
• Advanced technology with gearless direct drive, variable speed Synchronous generator with permanent magnet excitation
• No reactive power, no dependence on grid for excitation.
• Variable speed advantage offers high efficiency at low wind speeds.
• Full 900 pitchable blades offer aerodynamic breaking.
• Generator has concentric winding with flux concentration which boosts generator performance and efficiencies.
• Maintenance free highly reliable three independent pitch system

Foundation Concept Design for First Offshore Wind Project of India (FOWPI)

Dr. Martin Kelm
Technical Director
COWI, Germany

Gabriel Zeitouni
Project Manager &
Energy Specialist



Per Vølund
Project Director

COWI, Denmark

Executive Summary

The Government of India has recently released a call for Expressions of Interest (EoI) for 1 GW of offshore wind capacity. In addition, several more GWs are expected to be tendered as part of the following offshore wind implementation phases planned for India. In order to support the development of the sector in the country, a number of surveys and studies were initiated by the National Institute of Wind Energy (NIWE) and the European Union (EU). The concept design presented and discussed in this article is part of the project “First Offshore Wind Farm of India” (FOWPI), funded by EU and lead by COWI A/S.

Different offshore wind turbine foundations types have been discussed under the FOWPI project. After diligent investigations and consideration of the FOWPI site conditions, a monopile (MP) foundation type with a transition piece (TP) was selected as the most appropriate foundation type. The layout of the foundation elements, as well as the applicable loads and relevant environmental conditions of the site were defined in accordance with European standards and guidelines. Two concept designs were investigated, each for a previously defined reference wind turbine size, one for a 3 MW and another for a 6 MW. The MP and TP are linked by a conical grouted connection.

Based on the available data and preliminary assumptions, an MP with a bottom diameter of 5.50 m, a weight of 528.8 MT, and a length of 57.60 m was designed for the 3 MW model. Likewise, an MP with a bottom diameter of 7.00 m, a weight of 873.9 MT and a length of 63.00m was designed for the 6 MW model. Their respective design embedment lengths are 35.60 m and 41.00 m. The TP has a weight of 191.5 and 306.4 MT, respectively. Design basis are certainly to be refined once site measurements are available, as additional data would contribute to less uncertainty on the base assumptions, less conservative designs and reduced risks for project specifications in the area.

1. Introduction

India has one of the fastest growing economies in the world. In order to meet its rising energy needs, several GWs of new generation capacity must be added on an annual basis. Renewable energy has, for many years, been introduced in the Indian energy supply system and specifically onshore wind energy plays an important role. At present levels, there are approximately 34 GW of installed onshore wind power throughout the country. Numbers are quickly rising and by 2022 over 60 GW of wind is expected to be in operation in India.

In Europe, in addition to onshore wind, offshore wind has also become an important contributor to the regional sustainable energy mix. The total offshore wind farm capacity installed has already surpassed 14 GWs and numbers are continuously rising[9]. Given the required infrastructure and various challenges related to the offshore installation and operation, the costs for the first offshore wind farms were relatively high. However, thanks to market maturity and lessons learned in the design, manufacture, installation and O&M, the prices for new offshore wind projects are steeply declining and reaching record low subsidy free levels. In addition to countries surrounding the North Sea, including Denmark, Holland, Belgium, United Kingdom, Germany and other countries that have already installed offshore wind include China, USA and Taiwan.

For the success of the Indian offshore wind development, which is set to contribute to the ambitious renewable energy targets set for the country it is essential that the lessons-learned and the knowledge obtained in the mature European market are transferred to India. The FOWPI project outputs, including the Foundation Concept Design investigation, aims at assisting with such transfer.

This article presents the main findings from the concept design prepared for the offshore foundations of the prospected 200 MW offshore wind farm (OWF) near the coast of Gujarat, see Figure 1. The concept design has been prepared by COWI A/S on behalf of NIWE with the purpose of supporting a call for tenders. The present conceptual foundation study is based on the requirements set up in IEC 61400-3 and in the DNVGL family of codes and standards as also applied in Europe.

Figure 1: Location of the FOWPI 200 MW Concept Offshore Wind Project in Gujarat

Site-specific measurements with regards to metocean data (wind, waves, current and water level), detailed geotechnical and geophysical campaigns, as well as a detailed bathymetric survey are required in future detailed project design stages.

2. Foundation Types

Due to its magnitude and site-specific character, offshore wind foundations represent a significant part of a project's capital expenditure, and therefore optimization of its structure leads to substantial savings. In this regard, several factors are relevant to the foundation technology selection, i.e. water depth, wind turbine MW class, costs, ground conditions, installation vessels availability and local fabrication facilities between others. Typical foundation concepts are presented in Figure 2.

For the pilot site in question, three possible foundation types are considered: monopile (MP), jacket and concrete gravity based. Foundations types are illustrated in Figure 2.

Figure 2: Illustration of OWF Foundations Designed by COWI. From left: Thornton Bank Concrete Gravity based, Wikinger Jacket (Preliminary Stage), Two Times London Array Monopile, Nysted WTG and Rødsand 2 Offshore Substation Concrete Gravity Based

3. Selection of Foundation Type

Concrete gravity based foundations are the most economic between the three alternatives regarding the foundation material costs. The system is well proven for application in water depths of up to around 40 m. The structures can be manufactured as concrete elements, which are further transported by barges or vessels to the site and then placed on the (prepared) seabed. For the present case, the expected thick layer of soft soils directly below sea floor level, which has to be removed and replaced by a gravel bed for a gravity based foundation in order to provide a level and stable support, is considered costly and critical.

Steel jackets are used in European offshore wind farms at deeper sea (30-50 m) and for larger WTGs. From a manufacturing perspective, jackets demand a high number of welds or require expensive castings for the joints. Therefore, jackets are generally not used in shallow waters. The fabrication procedure for jackets in India is expected to be costlier than for monopoles in EU, even after consideration of the relatively lower workforce costs in India. The installation expenses for jackets are also relatively high due to the larger installation time needed compared to monopiles.

Monopiles are used in most offshore wind farms worldwide, and the technology is being constantly developed and improved for larger turbines and deeper locations. This system is currently applied in sites up to 40 meters deep, and for 6-8 MW wind turbines in its majority. Monopiles' rapid fabrication and installation processes lead to generally lower costs in relation to other foundation types. Furthermore, the water depth is relatively not very significant for the assumed FOWPI site area. Hence, COWI perceives it to be the most suitable option at the prospected OWF.

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RENEWABLE ENERGY

This selection is supported and summarized by the decision matrix documented in Table 1. This decision matrix is based on the method developed by Stuart Pugh, also called Pugh method or Pugh concept selection. It is a qualitative technique used to rank multi-dimensional options of an option set. The monopile is defined as the base case and the two other options are compared to it. The first column shows the selected criteria. No ranking is made for the criteria. "S" means "same" and shows no advantage. A minus sign indicates that the option is less advantageous and a plus sign indicated that the option is better regarding the respective criterion. All plusses and minuses are summed and the last row gives the total sum. Based on the selected criteria and available site-specific data jackets and gravity based foundations do not provide a better solution for the site compared to a monopile.

Table 1: Decision matrix based on the Pugh method

"S" means same level, a "+" or "-" indicates an advantage or disadvantage, respectively.

Criterion	Monopile (Base case)	Jacket	Gravity based
Water depth	S	-	S
Wind turbine MW class	S	S	S
Costs	S	-	+
Ground conditions	S	S	--
Installation vessel availability	S	S	-
Local fabrication facilities	S	S	+
Total +	0	0	2
Total -	0	2	3
Sum	0	-2	-1

4. Description of Monopile Foundations

A monopile foundation consists of a steel pile which is generally driven into the seabed soil. On top a transition piece (TP) is mounted. The TP contains a number of appurtenances, as illustrated in Figure 3, including working platforms, boat landing, J-tubes for cable protection and others.

London Array Offshore Wind Farm Monopile transition pieces

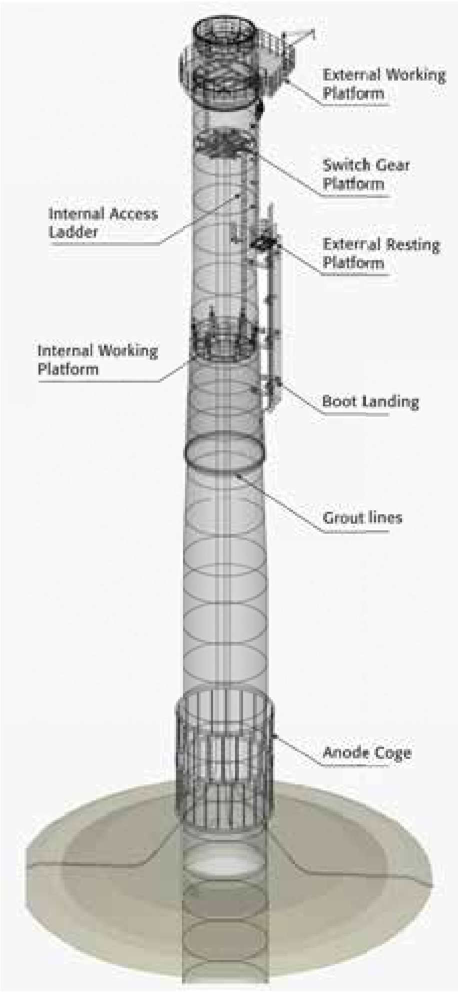

Figure 3: Schematic Illustration of Monopile Foundation including Some Secondary Steel Components

The connection between MP and TP may be either grouted, as in most of the current installed projects, or bolted, which is being frequently adopted in the latest European projects. For both cases, a skirt generally covers and protects the interface with the MP.

For this concept design a grouted connection is assumed, as designs that feature bolted connections do not present the same flexibility as those with grouted connections regarding the installation process and fabrication or installation tolerances.

Further, a scour protection is assumed, i.e. any changes of the seabed around the foundations are not considered in the presented studies.

5. Basis of Design

Several studies and investigations in relation the FOWPI project were made. They are published on NIWE and the FOWPI webpage[15]. In accordance with these studies and the currently available data, the basis for the foundation concept design is summarized in Table 2. It has to be noted that some of the assumptions have to be revisited once more site-specific data is available.

Table 2: Summary of Main Design Assumptions and Parameters

Description	Assumption	Reference
Codes and standards	DNVGL family of codes and standards and IEC standards	1,2,3,4,5, and 7
Foundation concept	Monopile with conical grouted connection	
Wind turbines	3 MW and 6 MW reference types	14
Design lifetime	27 years	
Water Depth	16 m	
Highest sea water level	+7.80 m LAT*	
Wind and wave loads	According to metocean study, also see Figure 4 and Figure 5	10
Maximum design wave level	+21.60 m LAT*	
Splash zone	-1.50 m to +7.00 m LAT	
Marine growth	According to ISO 19901-1:2005	8
Soil conditions	See design soil profile in Figure 6	R10
Seabed changes	Scour protection and no bathymetrical changes assumed	
Earthquakes	One time bottom diameter of MP added to pile embedment length	12/

* derived from extreme conditions from cyclone assessment[11]

Figure 4 shows the rose plot of the significant wave heights for the site. The provided data is for one extraction point for the period 2010 to 2014. The data does not reflect cyclone conditions.

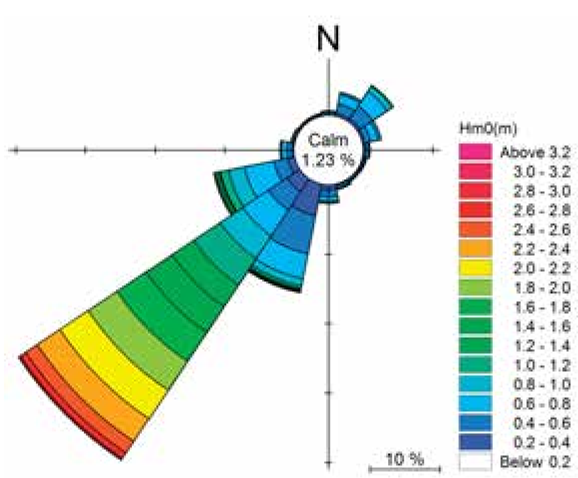

Figure 4: Rose plots of significant wave height (Hm0) at one extraction point from 2010 to 2014

Figure 5 shows the rose plot of the wind speed for the site. The provided data is for the period 2010 to 2014 given at a height of +10 m MSL (+12.11 m LAT). The data does not reflect cyclone conditions.

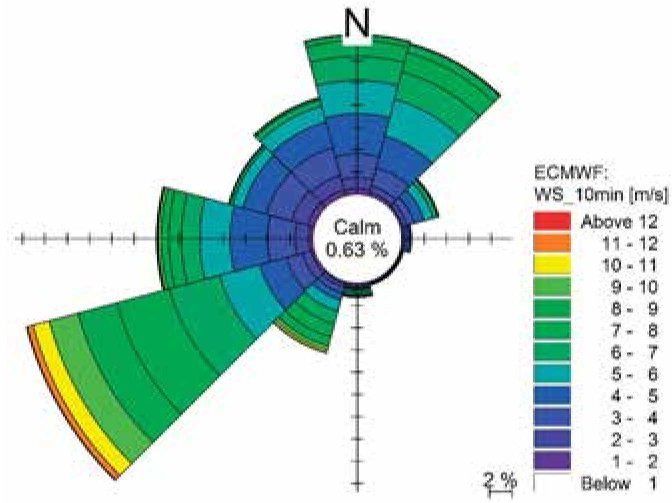

Figure 5: Rose Plot of Wind Speed at 10 m (U10), at One Extraction Point from 2010 to 2014.

A schematic view of the design soil profile as used in this study is presented in Figure 6, also see Reference No. 13. The given levels are with respect to mudline/sea floor level, i.e. a value of zero is equal to sea floor level. The upper part is composed of very soft clays. Below -9.5 m with respect to sea floor level, the soil changes to mainly very dense sands.

Due to the very soft clays just below the sea floor, a gravity based foundation is not a favourable solution for this site.

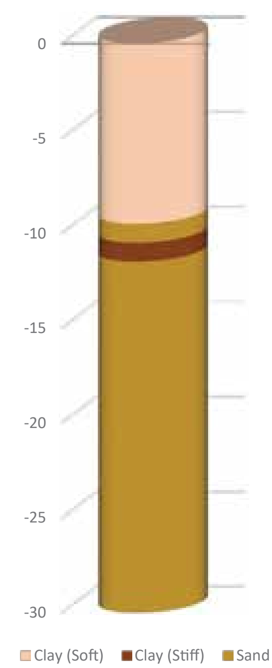

Figure 6: Schematic View of Design Soil Profile at the Project Site. Note: 0 m is Equal to Mudline

6. Foundation Design

The foundation design is carried out based on the assumptions and environmental conditions as summarized in Table 2. Two different generic wind turbines are investigated, a 3 MW and a 6 MW. Both WTGs are further detailed in Reference 14. For these two turbine types, loads are established for ultimate (ULS) and fatigue limit (FLS) states. Designs are made with respect to such states.

The interface level between the tower and the TP, and consequently the level of the external working platform is determined according to the environmental conditions specified in Table 2. The bottom of the external working platform is defined at +23.30 m LAT, after considering the maximum design wave level and an air gap of 1.7 m. A structural platform height of 0.5 m is assumed leaving the top of the external working platform at 23.80 m LAT. The interface level is therefore defined at +24.00 m LAT.

The bottom of TP is determined to -4.0 m LAT, covering the splash zone and providing sufficient height to attach a boat landing structure to it. The top of MP is set to +6.0 m LAT. The resulting TP and MP geometries and weights considering these basic geometrical constraints are given in Table 3.

Table 3: Basic Result Table for Weights and Lengths of Monopile Foundations

Turbine Model	[Unit]	3 MW	6 MW
Mass of TP	[MT]	191.5	306.4
Length of TP	[m]	28	28
Top diameter of TP	[m]	4.5	6.0
Bottom diameter of TP	[m]	5.5	7.0
Wall thickness range of TP	[mm]	55-65	60-90
Mass of MP	[MT]	528.8	873.9
Length of MP	[m]	57.6	63.0
Embedment length of MP	[m]	35.6	41.0
Top diameter of MP	[m]	4.4	5.9
Bottom diameter of MP	[m]	5.5	7.0
Wall thickness range of MP	[mm]	55-80	60-100
Length of cylindrical section of MP	[m]	41.85	47.25
Length of conical section of MP	[m]	15.75	15.75

7. Conclusions and Recommendations

Three foundations types are discussed for this project: monopile, jacket and gravity based. Considering the site conditions based on available data, it is found that a monopile foundation is the most appropriate for the FOWPI site area. A monopile (MP) foundation type with a separate transition piece (TP) connected by a conical grouted connection is considered as a reliable and robust concept for this project.

The decision for the foundation type might be reconsidered in the future based on more data availability from site measurements. It is expected, however, that a monopile type of foundation would still be the most favourable choice. In any case, additional data will certainly contribute to less uncertainty on the base assumptions and less conservative designs. All of which would contribute to reduced risks, and potentially reduced costs, for future detailed project designs in the area.

Thornton Bank Offshore wind farm Gravity Foundations

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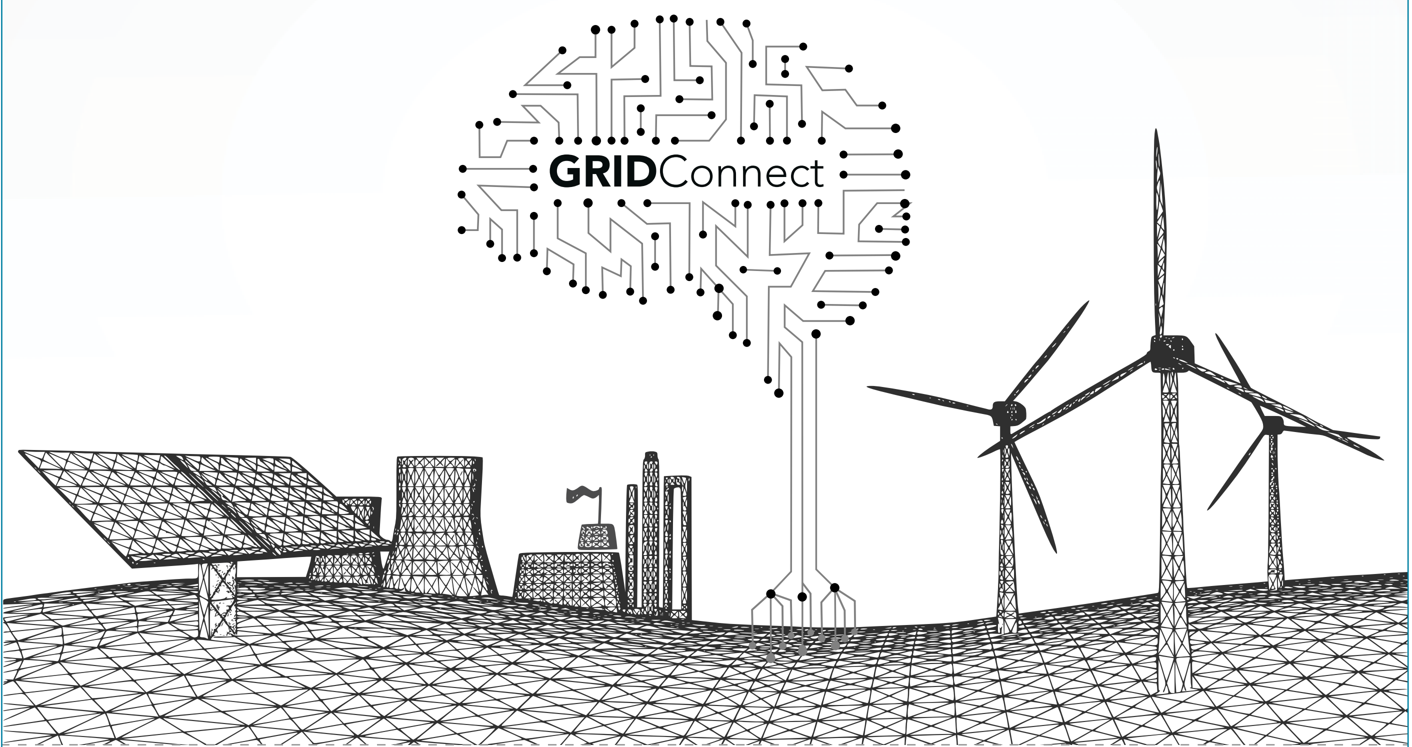

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Wikinger offshore wind farm - Jacket Foundations

Performance Optimization - How SCADA Mining and Deep Learning Techniques can address Post-construction Requirements of the Wind Power Industry?

Karim Fahssis, AZIUGO, Lasalle, France, **Michel Nocture,** Mines ParisTech, Paris, France
Sunil Talla, Ecoren Energy India Private Limited, Hyderabad, India

Abstract

Ecoren is developing, constructing, owning and operating wind power projects built for lasting success. In order to identify high value opportunities in the wind energy sector in India and then create and implement a plan to convert those opportunities into operating assets, Ecoren is putting a lot of efforts on investigating wind resource patterns over the whole country.

Becoming the leading IPP in India also means getting the most out of operating projects, by using the latest deep learning algorithms offered by AZIUGO. Through this validation exercise, Ecoren has witnessed the power of this technology on 3 turbines:

- The detection of underperformances on their turbines made them aware that they were losing money.
- The exact date of the start of underperformances and the diagnostic to correct them and made them able to increase their benefits.
- By avoiding upstream multiple tests, the specific detection of the problem let Ecoren save money from their O&M operations.

Ecoren requested Aziugo to carry out a diagnostic analysis on 3 of their under-performing Wind Turbine Generators on the site of Dhone on May 2, 2017. The SCADA data of the turbines n°4, n°7 and n°9 were provided to Aziugo's Consultant, on May 25, 2017.

This report presents the results of the SCADA analysis performed by Aziugo's consultants using deep learning tools. It describes the under-performances detected throughout this study and provide guidance on how to solve these under-performances.

Part I
SCADA DATA ANALYSIS

1. Wind Speed Distribution

The SCADA Data recorded from December 2016 to May 2017 shows that the wind speed is approximately the same on the three turbines. However, the turbine n°4 has slightly more wind than the turbines n°7 and n°9. This subtle trend is more visible on the power output statistics.This is summarized in Table 1.

Table 1: Wind Speed and Power Output Summary

	Turbine n°4	Turbine n°7	Turbine n°9
Mean Wind Speed ($m.s^{-1}$)	5.5	5.0	5.0
Mean Power Output (kW)	338.6	277.2	254.1

Figures 1 and 2 show the wind speed repartition respectively for the turbine n°4, n°7 and n°9.

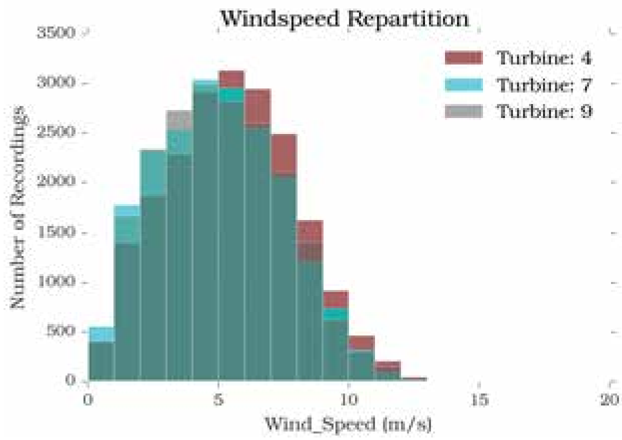


Figure 1: Wind Speed Distribution on the Turbine n°4, n°7 and n°9

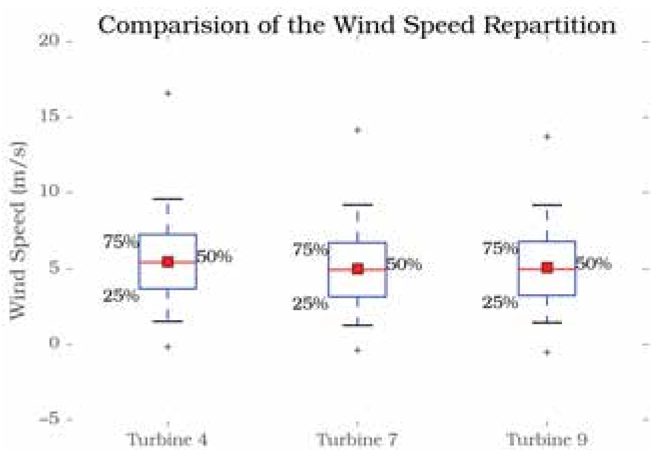
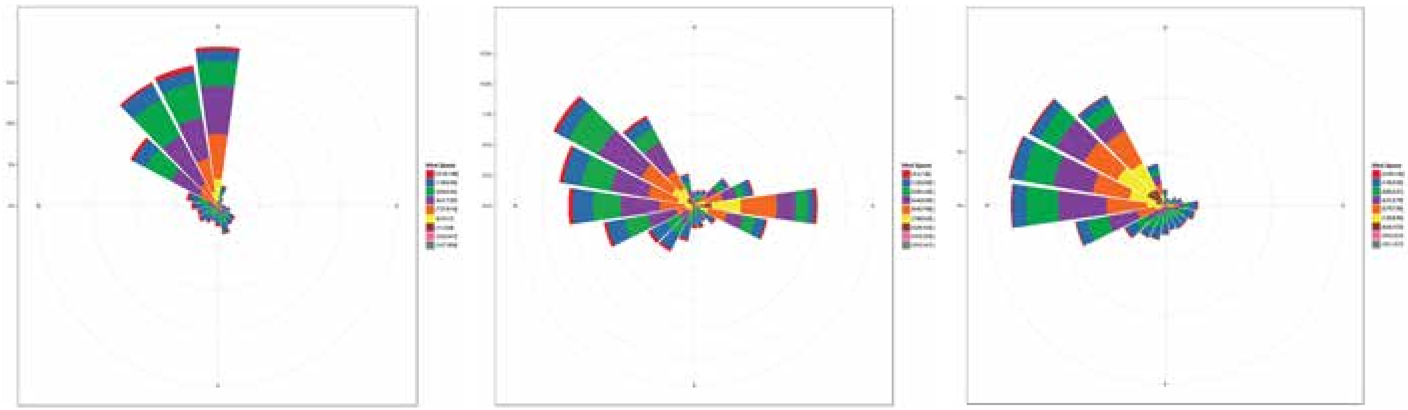


Figure 2: Statistical Wind Speed Distribution for the Turbine n°4, n°7 and n°9

2. Wind Direction Distribution

Surprisingly, the turbine n°4 does not have the same wind direction distribution than the two others. Indeed, for this turbine the prevailing directions are from North-West to North while the prevailing directions for the turbines n°7 and n°9 are East to North-East as it can be seen in the Figures 3a, 3b and 3c.



(a) Turbine 4 *(b) Turbine 7* *(c) Turbine 9*

Figure 3: Wind Rose on each turbine location

We can observe something strange in the wind rose of the turbine n°7, the wind direction seems to have change during the months of recording. We see in Figure 4 that in March, the wind direction of the turbine n°7 has changed of nearly 180°compared to the other months. That may be explained by a problem of the Wind Vane on the turbine.

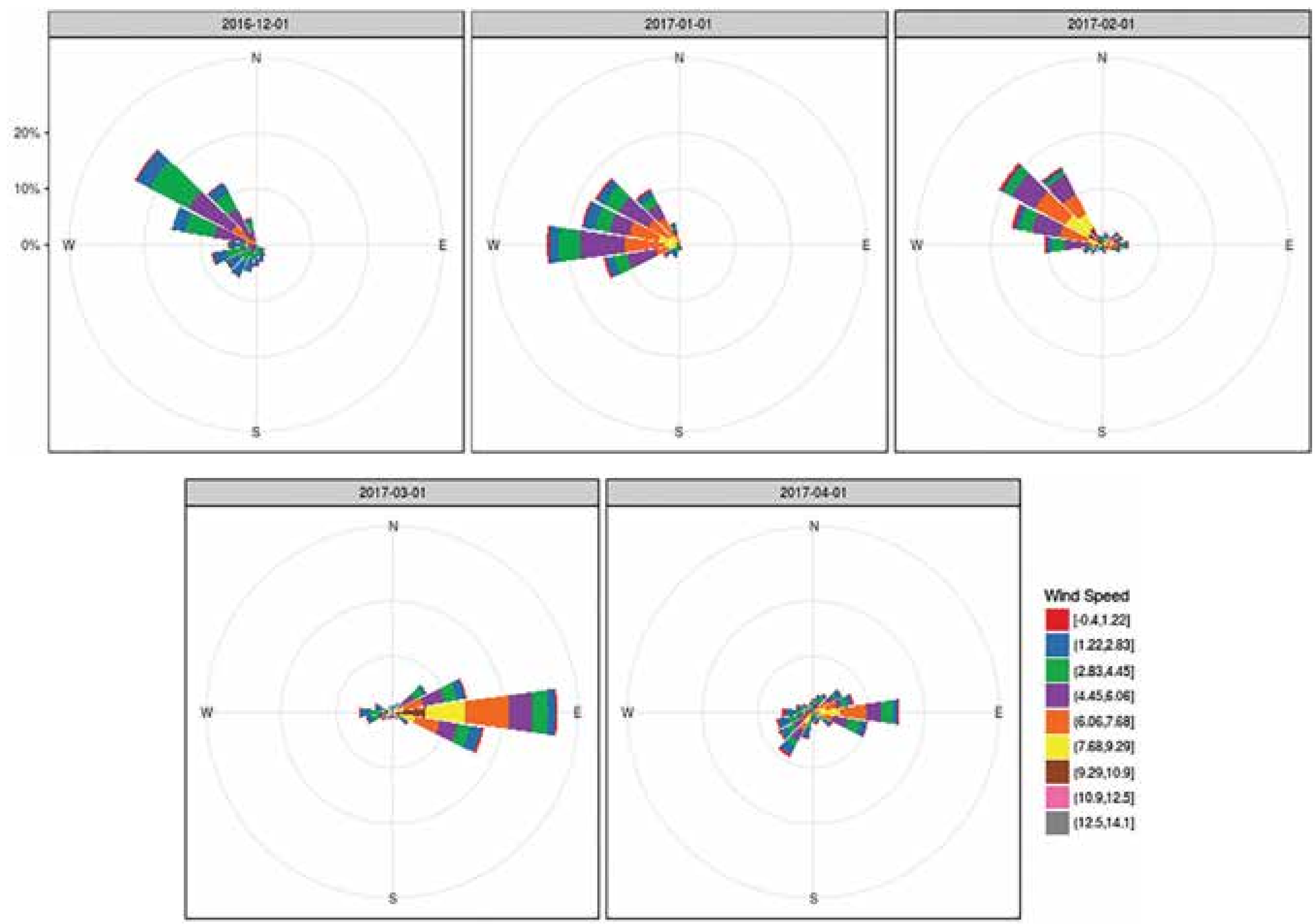


Figure 4: Wind Rose of Turbine n°7 - Each subplot corresponds to a month

This change can have several consequences on the performances of the turbine.

However, this problem has not been spotted on the two other turbines although they suffer the same shift. Moreover, the huge fall in the power output is related to mid-end of February, before the possible mis-functioning of the instruments.

3. Power Output

Given the wind speed distributions on the turbines n°4, n°7 and n°9 it is expected that the power production of the turbines n°7 and n°9 are slightly lower than the power production of the turbine n°4. Figure 6 shows the statistical distribution of the power production for all the turbines and the Figure 5 shows the Power Output Repartition into bins.

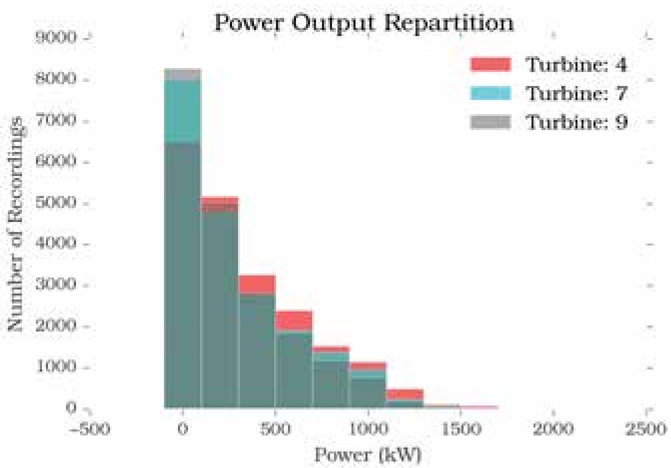


Figure 5: Power Output Distribution on the Turbines n°4, n°7 and n°9

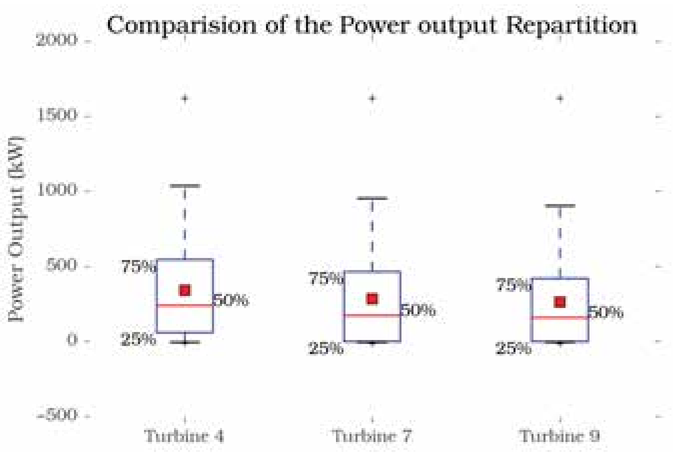


Figure 6: Statistical Power Output Distribution for the Turbines n°4, n°7 and n°9

Table 2 summarizes the statistics for these three turbines.

Table 2: Summary of wind speed and power output distributions

	WS 4 (m.s–1)	WS 7 (m.s–1)	WS 9 (m.s–1)	Power 4 (kW)	Power 7 (kW)	Power 9 (kW)
Average	5.5	5.0	5.0	338.6	277.2	254.1
Q1 (25%)	3.67	3.09	3.17	55.975	-1.57	-2
Median	5.43	4.88	4.9	233.7	159.5	146
Q3 (75%)	7.19	6.69	6.76	540.425	452.35	407.9

4. Generator RPM

4.1. Turbine n°4

A change on the Generator RPM behavior can be seen during the month of February 2017. Between January and February, the Generator RPM curve shifts slightly toward the right as described by the red arrows in Figure 7 which presents the Generator RPM versus wind speed; each subplot corresponds to a month of recording. On the other hand, between March and April 2017, the Generator shifts to the left, back to a better-performing behavior.

4.2. Turbine n°7

The same conclusions can be drawn from the turbine n°7, the generator RPM presents a change between January and February 2017 as shown in Figure 8 with the red arrows. The opposite change can be seen between March and April 2017.

4.3. Turbine n°9

Turbine n°9 presents similar symptoms in a more significant way: the generator RPM clearly changed between January 2017 and February 2017 in one way; and between March and April 2017 in the other way, as shown in Figure 9 with the red arrows.

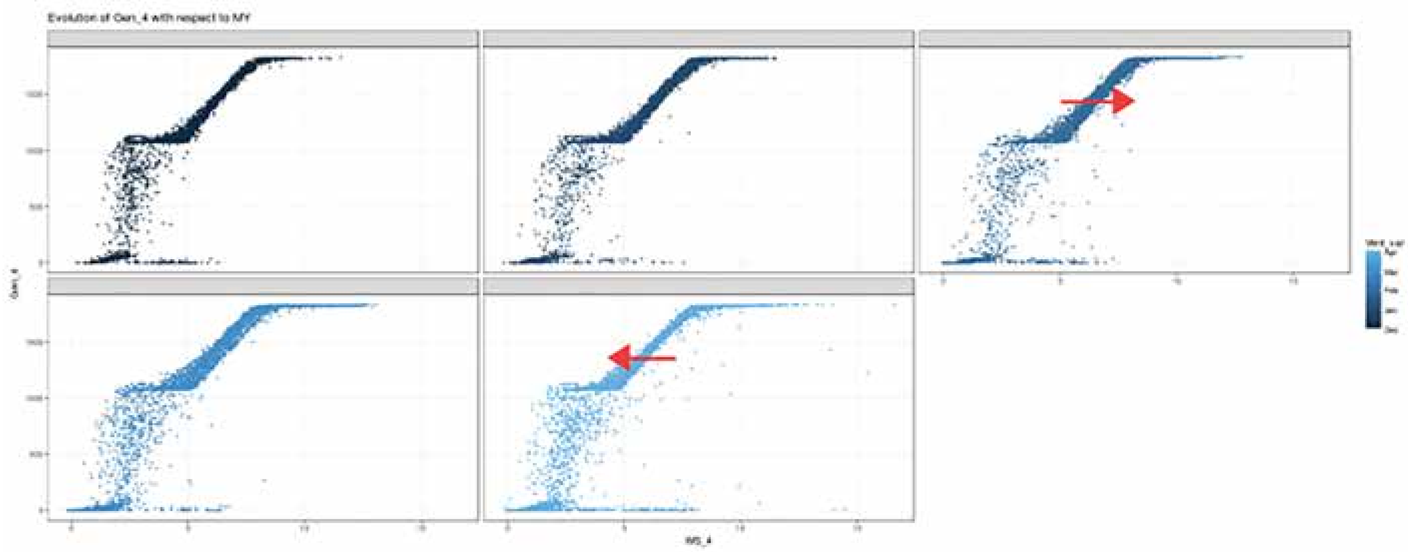


Figure 7: Turbine n°4: Generator RPM vs Wind Speed - Each subplot corresponds to a month

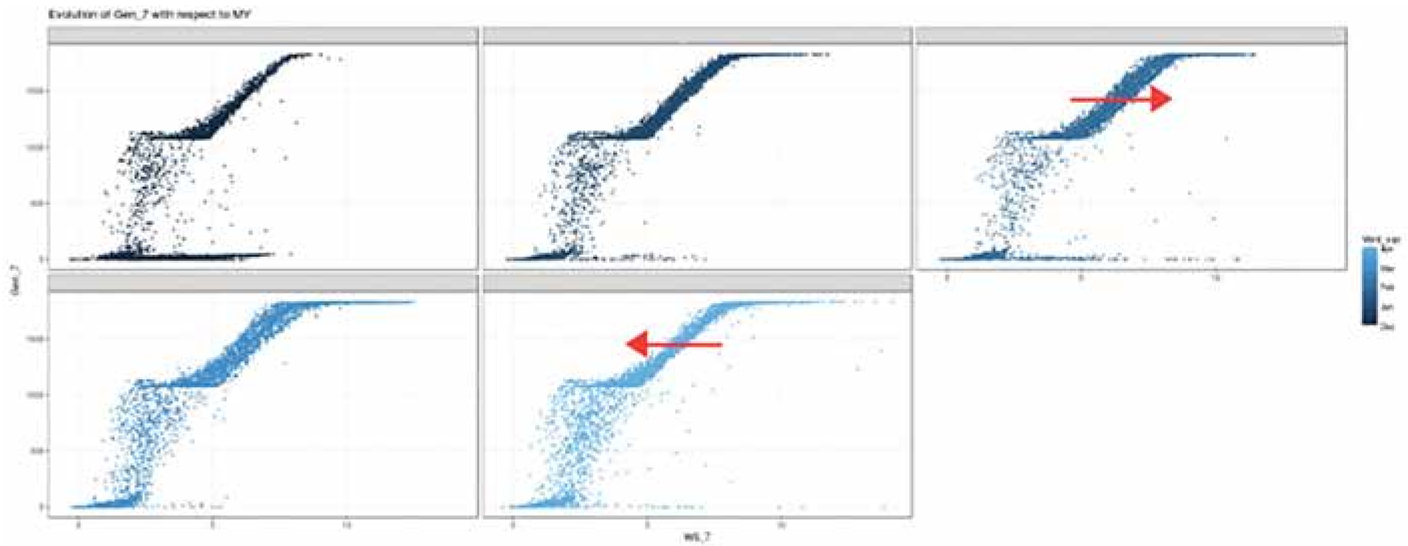


Figure 8: Turbine n°7: Generator RPM vs Wind Speed - Each subplot corresponds to a month

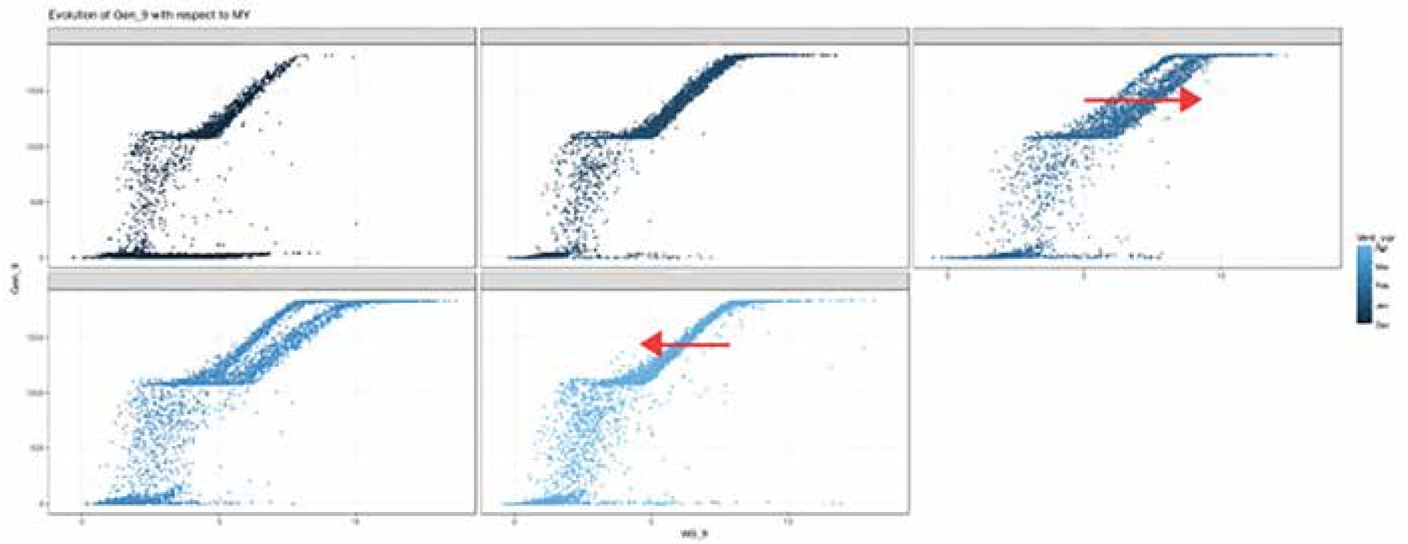


Figure 9: Turbine n°9: Generator RPM vs Wind Speed - Each subplot corresponds to a month

Part II

DEEP LEARNING MODELING

1. Theory Description

Based on the SCADA Data, the SCADA Mining software uses a deep learning algorithm to model the normal behavior (i.e., the power output, Pitch Angle or Generator Speed) of the turbine give the wind speed, the wind direction and the temperature (to have an estimation of the air density). It is based on neural networks. Like the neural networks that exist in your brain, artificial neural networks are based on recognition of situations (inputs) and the appropriate reaction (output).

First, you have to give a sample of SCADA Data as a training sample. The neural networks will analyze the inputs and output of this training set to build the model. The model is a set of ways to react to different inputs. Then, you can validate your model by testing it on the remaining SCADA Data, which were not used in the training set. The links created between the inputs and the output enable you to see the differencies between the good behavior of the turbine (based on the SCADA Data of the training set) and the actual behavior of the turbine.

As we can see, neural networks accuracy are highly based on the data of the training set. Therefore, it is very important to use data that actually shows the good behavior of the turbine. The flagging step is very important as we will see it in the following part.

A scheme of two hidden layers is presented in Figure 10.

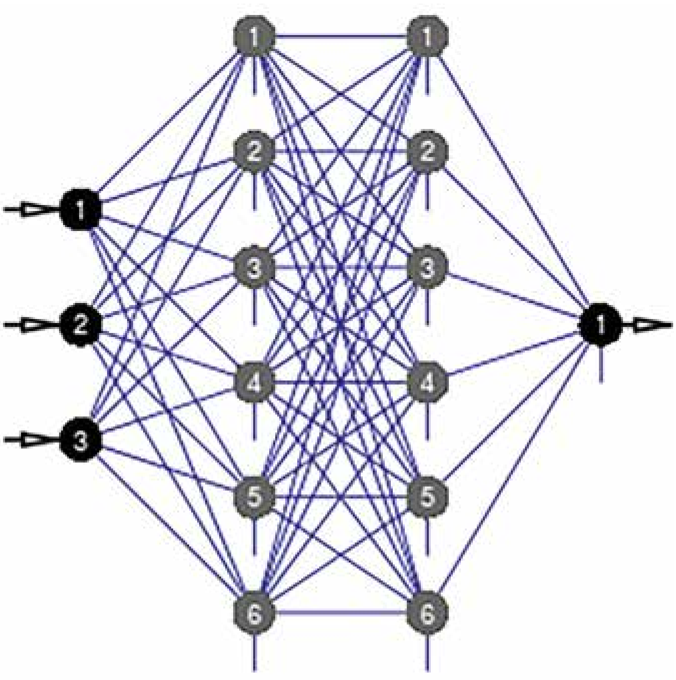


Figure 10: Scheme of a two hidden layers neural network with three inputs and one output

As we can compare the behavior, and thus the power output, of the model to the reality we can detect when these two behaviors split. This way we can know when the problem started, as it is often related to maintenance operation we can tell what is the root cause of the issue.

2. Flagged Data

The first step of the SCADA Data analysis is to select the measurement points, corresponding to the "normal behavior". Figure 11 shows the selection of the data corresponding to the normal behavior along with the data flagged as "SUSPECT" or "STOPPED".

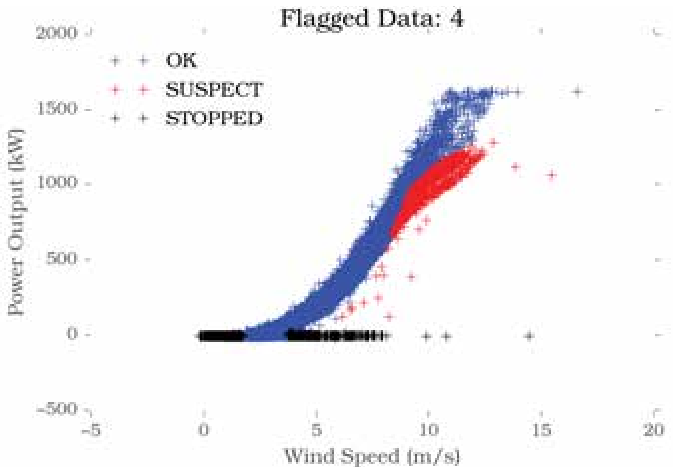


Figure 11: Flagged data for the model of the Turbine n°4

The data selection (or "flagging") is very important as it selects the data, which will be used to create the model, a poor data selection will always result in an inaccurate model and wrong diagnostic. Table 3 summarizes the proportion of flagged data.

Table 3: Data flagging summary - Number of recording for each state

	Turbine N°4	Turbine N°7	Turbine N°9
OK	18,628	17,646	14,241
STOPPED	620	2,579	4,016
SUSPECT	1,649	562	4,779
TOTAL	20,897	20,787	23,036

At this stage, we can notice that the turbine n°9 has more flagged data than the other turbines. It means that it has more often an unexpected behavior than the turbine n°4 and n°7.

3. Accuracy of the Model

As said previously, the more data that represents a good behavior you have in the training set, the more accurate your model will be. In order to evaluate the accuracy of the model, we have to compare the model of a good behavior with data of a good behavior that has not been used for the training set. That means that we used data flagged as OK for the training and testing step. Here are the results for a 60% training set and 40% testing set. The accuracy of the model is quantified by two parameters automatically calculated: the residual distribution and a linear regression of the estimated variable versus the measurement of the SCADA Data.

An accurate model has its residual distribution centered on the value 0 and it should look like a Gaussian distribution.

The linear regression should have a slope of 1, a very low offset and a Determination Coefficient R^2 as close as possible to 1.

3.1. Residual Distribution

The residual distribution of the model for the turbine n°4, n°7 and n°9 are shown respectively in Figures 12, 13 and 14.

From these three graphs we can see that the residuals are centered on the value 0 and are symmetrical which is a guarantee of quality. In addition, more than 95% of the residuals are included in the interval [-0.1,+0.1] which is the difference between the model and the measurements.

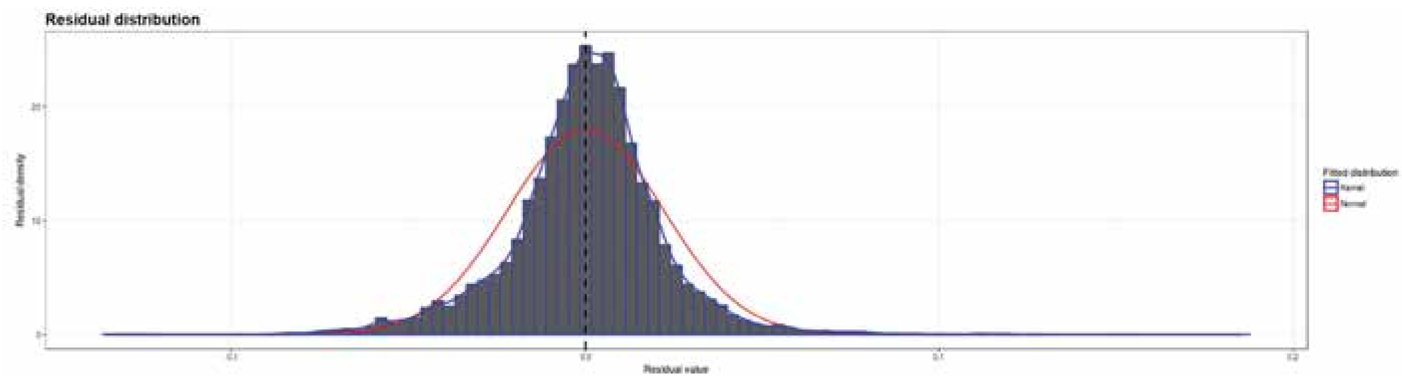


Figure 12: Residual distribution of the model of the Turbine n°4

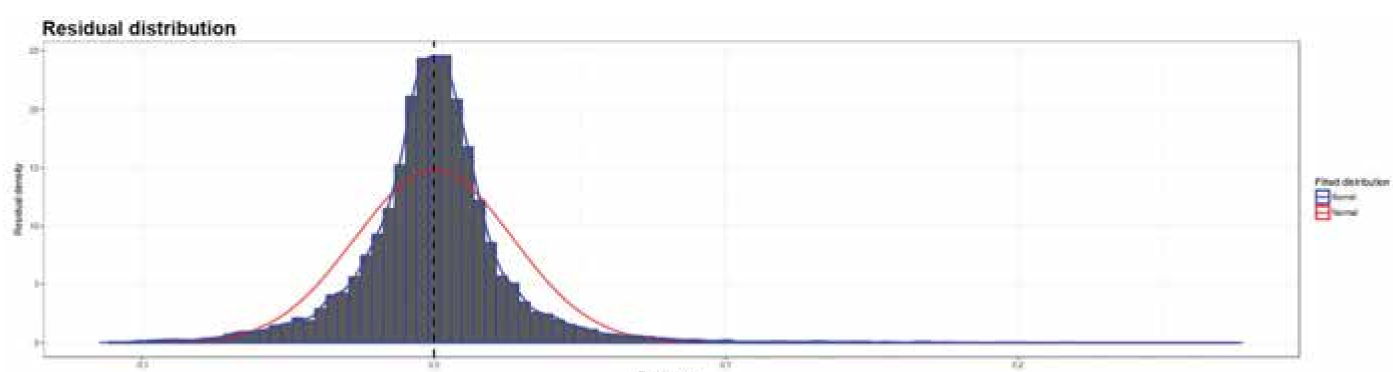


Figure 13: Residual distribution of the model of the Turbine n°7

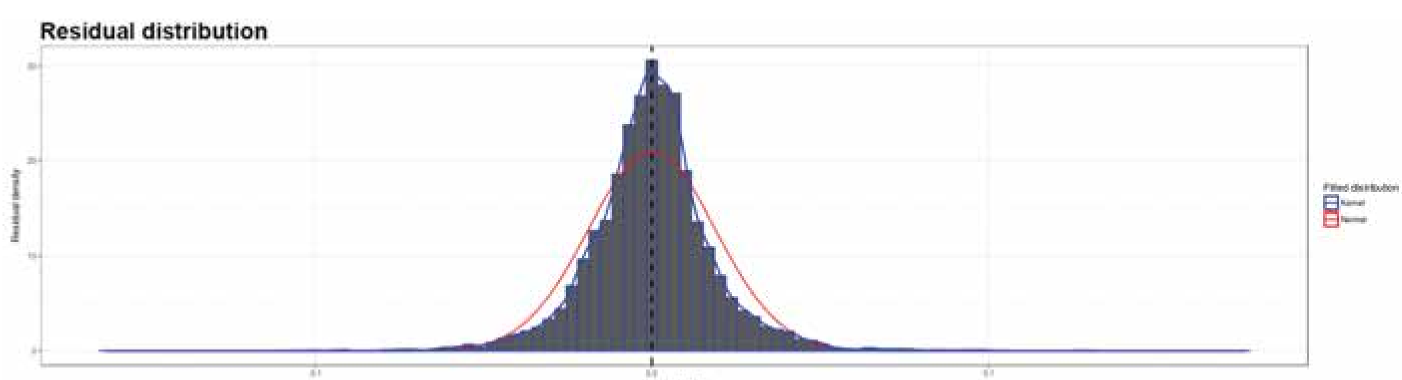


Figure 14: Residual distribution of the model of the Turbine n°9

3.2. Linear Regression

The linear regression of the model versus the SCADA measurements for the turbine n°4, n°7 and n°9 are shown respectively in Figures 15, 16 and 17. As you can see, the points at high power are very scattered, this is due to the Generator's behavior.

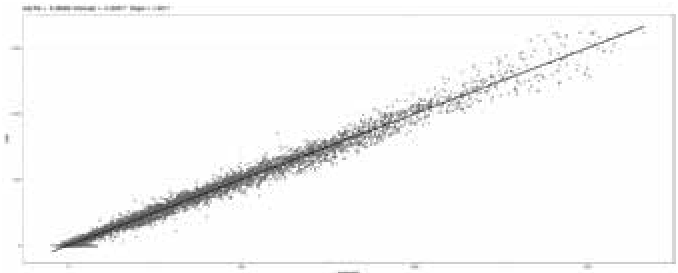


Figure 15: Linear regression of the model versus the measurements: Turbine n°4

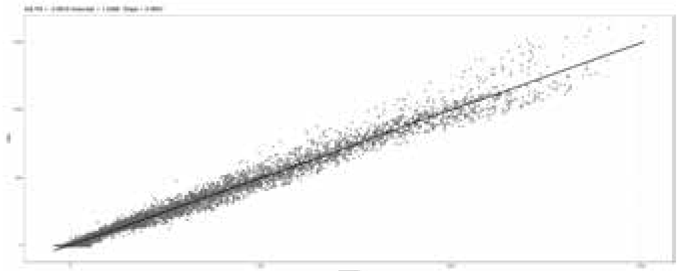


Figure 16: Linear regression of the model versus the measurements: Turbine n°7

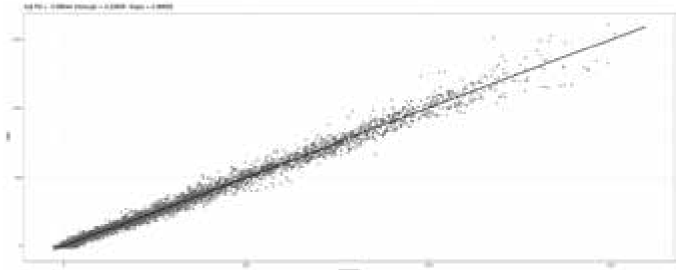


Figure 17: Linear regression of the model versus the measurements: Turbine n°9

All the models have a coefficient of determination R2 higher than 0.98, slopes very close to 1 and low offset (below 1 kW). These quantitative parameters guarantee the quality of the model, they are summarized in Table 4.

Table 4: Accuracy Summary

	Turbine N°4	Turbine N°7	Turbine N°9
R^2	0.9870	0.9824	0.987
Slope	1.0016	1.0011	1.0005
Offset (kW)	-0.6415	-0.5116	0.0094

4. Power Output Chronogram

Once we are sure that our model is accurate enough, we can start looking at the differences between the modeled behavior and the actual behavior. The power output chronogram shows the deviation between the two behaviors - month by month or week by week.

Deviation is calculated with:

$$\text{Deviation} = 100 * \frac{\text{Actual - Modelization}}{\text{Actual}}$$

The three turbines n°4, n°7 and n°9 show under-performances during the months of January, February and March 2017 compared to the well-performing behavior in December 2016. After March 2017 the performances are back to what it was before January 2017. During the under-performances period changes on the Generator RPM behaviors of every turbine have been detected. No change in the pitch has been detected in the data recorded (see Figure 18).

The under-performances are most likely to be due to maintenance operation done on the turbines. It seems that the OEM company in charge of the maintenance has changed the generator behavior in early 2017 and corrected it in mid-March (around March 20^{th}).

Visualizations of the under-performances compared to the model and visualizations of the Generator RPM behavior are shown in the sections 4.1, 4.2 and 4.3.

4.1. Turbine n°4

The chronogram in Figure 19 shows the deviation of the power output from the model on the turbine n°4. It highlights under-performances (up to 15% during week 9) from January 2017 to March 2017 but these under-performances have been corrected by April. The weekly chronogram in Figure 20 shows more precisely this trend, it started during the 2^{nd} week of 2017 (January 9^{th} to January 15^{th}) and ended in mid March.

There are high chances that maintenance operations have been performed on this turbine in the beginning of 2017. These actions are very likely to have caused the under-performances, after Ecoren reported this to the OEM it seems that the OEM took corrective actions in March.

Finally, after modeling the behavior of the average good performing wind turbine and comparing it to the real production we can see that the under-performances last from January to March 2017 and more precisely from the 2^{nd} to the 11^{th} week of 2017 (i.e. February 8th to March 13^{rd}) see Figure 20.

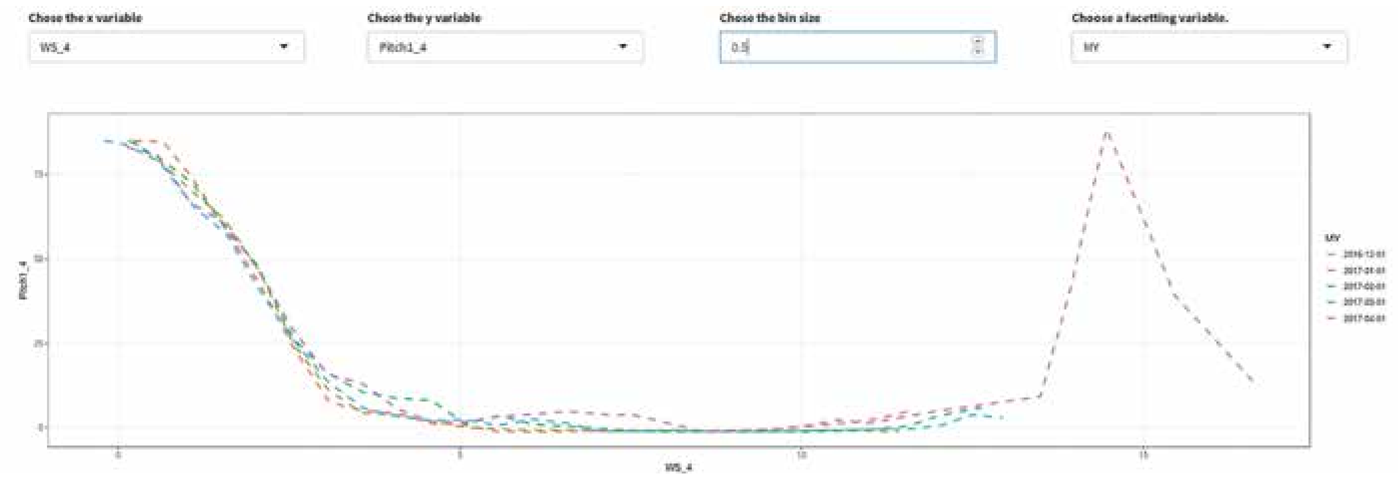


Figure 18: Turbine n°4: Pitch vs Wind Speed - Each curb correspond to a month

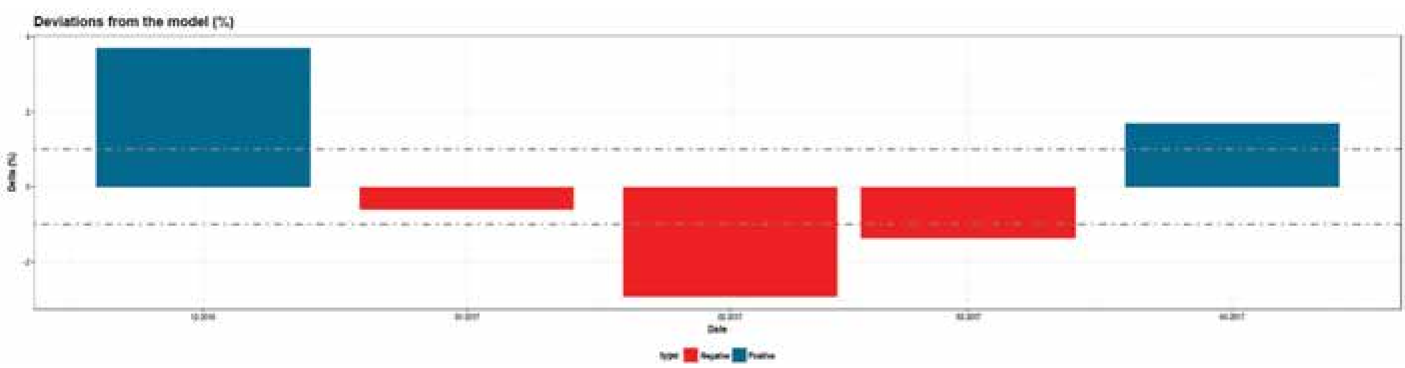


Figure 19: Turbine n°4: Deviation of the real production compared to the modeled one - Month by month

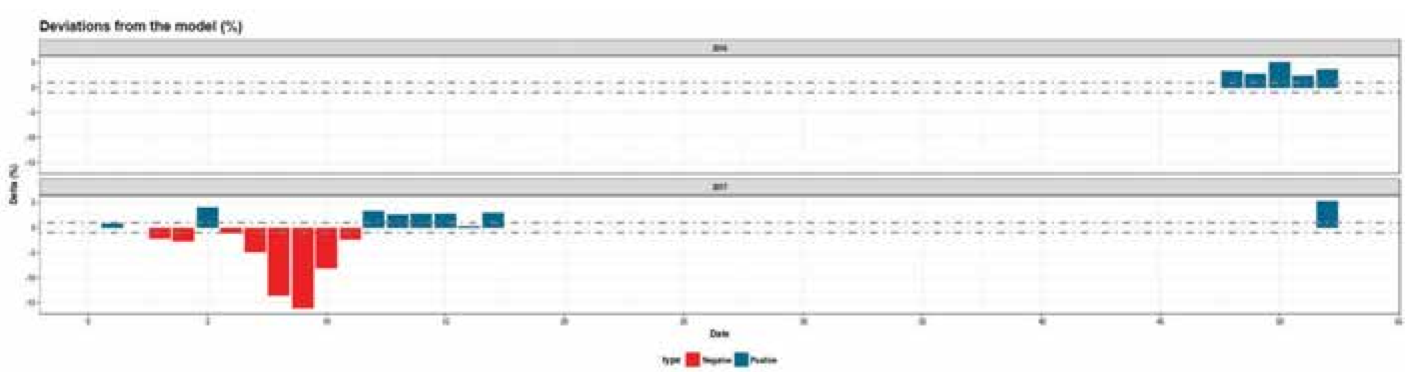


Figure 20: Turbine n°4: Deviation of the real production compared to the modeled one - Week by week

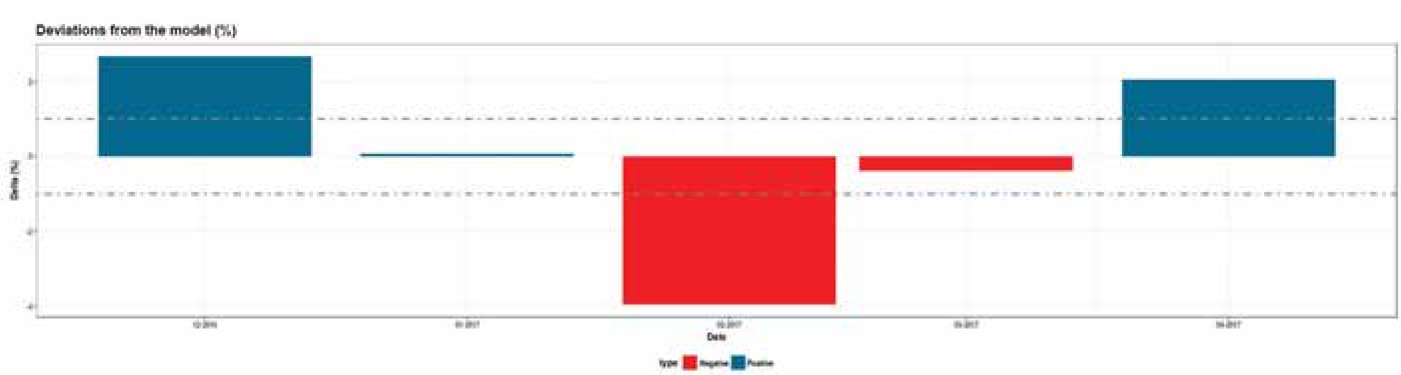


Figure 21: Turbine n°7: Deviation of the real production compared to the modeled one - Month by month

4.2. Turbine n°7

The chronogram in Figure 21 shows the deviation of the power output from the model on the turbine n°7. This deviation is similar to what can be observed on the turbine n°4. So the same conclusions can be drawn from this analysis. Some outstanding data make the weekly deviation graph unrelevant that is why it is not displayed here.

4.3. Turbine n°9

The chronogram in Figure 22 showing the deviation of the power output from the model on the turbine n°9 is clear that under performances started during the month of January. The weekly chronogram shows more precisely that the performance drop started during the 3rd week of 2017 and reached its peak on week n°8 (February 20th - Up to 100% of under-performances). As it follows the same chronology of the turbines n°4 and n°7, the same scenario happened to the turbine n°9 and it impacted more the power generation than for the other two.

For the same reason as for the turbine n°7, weekly visualisation of the deviation of the power output is unrelevant for the turbine n°9.

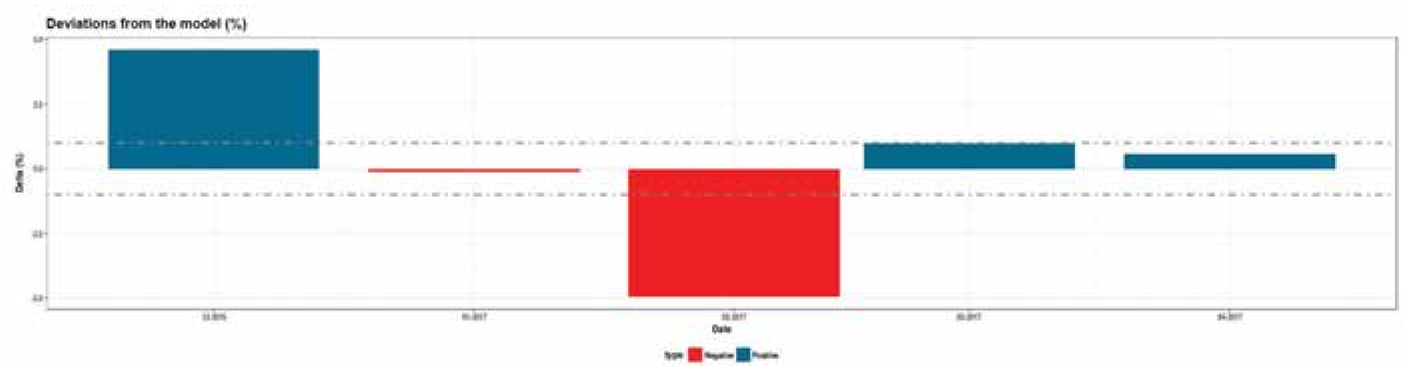


Figure 22: Turbine n°9: Deviation of the real production compared to the modeled one - Month by month

Part III

CONCLUSION

The SCADA Data provided by Ecoren were recorded from December 2016 to May 2017. They have been analyzed by Aziugo's Data Analyst during June 2017.

A problem occurred on the three turbines from January to March 2017 as we can see a shift to the right in the power output curve on the three turbines.

No change on the pitch of the turbines has been spotted. A change in the wind direction of the turbine 7 has been noticed in March but it is not the cause of the recorded shift. There might be a problem on the Wind Vane of the turbine and it could lead to other under-performances but Aziugo does not have enough data to know if this problem is still there.

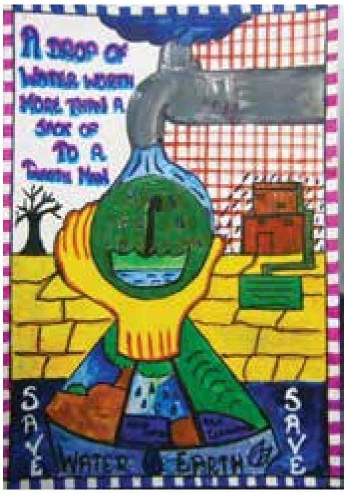
The cause of the recorded shift should have been some maintenance action on the Generator RPM controller during the 1st or 2nd week of 2017. It appears that a corrective action has been done in mid March getting the turbine to the performance level of December 2016 as predicted by our analysis.

It is clear that SCADA Data is a gold mine and its analysis can lead to an increase in the performances of the turbines. It enables companies to detect under-performances with a high precision and can provide several advices in order to correct it.

The use of deep learning with SCADA Data enables to identify the optimal performances of a turbine and to model it to detect a strange behavior of the turbines. This leads to reducing uncertainties and prevent different issues.

Global Wind Day Painting Competition

Indian Wind Turbine Manufacturers Association organized a painting competition among students of various schools to celebrate Global Wind Day 2018. Photographs of winning paintings who participated in painting competition are given below.



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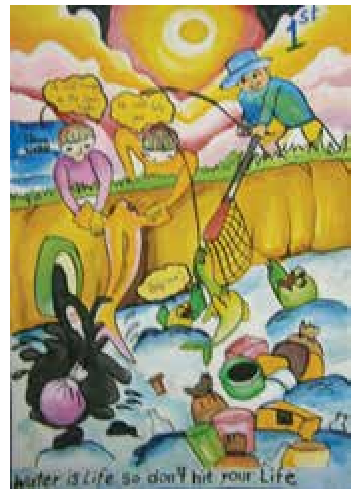
(Arwachin Bharti Bhawan School)

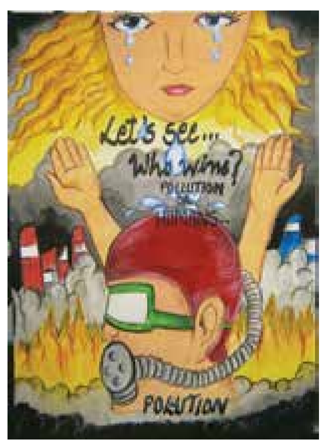
Gourav Bhatnagar
(Arwachin Bharti Bhawan School)



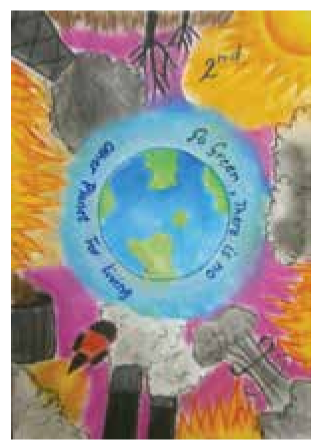
Devanshi Sharma
(Dayanand Model School)

Tarun Kumar
(Mahashay Dharampal Vidya Mandir)

Ashmit Raj (Arwachin Bharti Bhawan School)



Sameer Kumar Jha
(MDH International School)

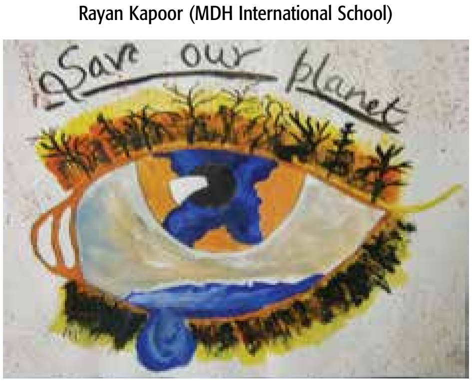


Chirag Gupta
(Dayanand Model School)

Rohit Choudhary
(Mahashay Dharampal Vidya Mandir)

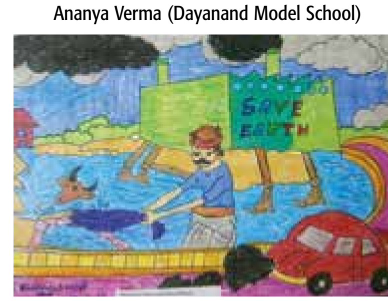
Rayan Kapoor (MDH International School)

Ananya Verma (Dayanand Model School)



Mansi Sharma (MDH International School)

Yash Gola (Mahashay Dharampal Vidya Mandir)



Kuwardeep Singh (Mahashay Dharampal Vidya Mandir)

Photo Feature

Annual General Meeting and Members Meet of Indian Wind Turbine Manufacturers Association

Indian Wind Turbine Manufacturers Association conducted its 14th Annual General Meeting and Members Meet on 23rd June 2018 at Hotel Redisson Blu, Chennai. Shri Tulsi Tanti, Chairman addressing the members. The Photograph of the event is given on the right.

Second Indo-Spanish Wind Supply Meet 2018

In cooperation with Indian Wind Turbine Manufacturers Association (IWTMA) and Navarra Widn Supply (NAWIND), Government of Navarra (Spain) organised Second Indo Spanish Wind Supply Meet on June 12, 2018 at Hilton, Chennai to deliberate on wind sector in order to strengthen the ties and discuss about the current scenario of Indian Wind Sector. A photograph of the event is given below.

Round Table 1: Indian Wind Sector Current Scenario: From Left to Right: Mr. Inaki Soto, Managing Director, Indversis; Mr. M.S. Madanagopal, AVP, Siemens Gamesa; Mr. D.V. Giri, Secretary General, IWTMA and Mr. S. Gnanasekharan, Secretary General, IWPA.

Stakeholders Consultation Workshop on 'Addressing Barriers to Scaling-Up Renewable Energy in Southern Region of India'

The Indian Renewable Energy Federation (IREF) in partnership with Idam Infrastructure Advisory Pvt. Ltd. (Idam) and Indian Wind Turbine Manufacturers Association (IWTMA) organized a Stakeholders Consultation Workshop on 'Addressing Barriers to Scaling-Up Renewable Energy in Southern Region of India' on 08 June 2018 at GRT Grand, Chennai. The initiative was supported by Shakti Sustainable Energy Foundation (SSEF).

From Left to right : Mr. A.S. Karanth Wind Energy Consultant, Co-Chair: Mr. D.V. Giri, Secretary General, IWTMA, Chair: Dr. K. Balaraman, Director General, NIWE, Mr. N. Ramani, Head, Corporate Affairs, Suzlon and Mr. Neeraj Gupta, RenewPower

Global Wind Day Painting Competition

IWTMA organised painting competition among children from various schools in New Delhi on the theme of Global Wind Day. The winners along with their teachers, chief guest and other dignitaries on Global Wind Day Celebrations at New Delhi on 30th June 2018.

Photo Feature

Global Wind Day Celebration by IWTMA

Indian Wind Turbine Manufacturers Association celebrated Global Wind Day on 30th June 2018 at New Delhi and the event was inaugurated by Shri Anand Kumar, Secretary, Ministry of New and Renewable Energy, Government of India, as Chief Guest. A few photographs of the event are presented below.

Printed by R.R. Bharath and published by Dr. Rishi Muni Dwivedi on behalf of Indian Wind Turbine Manufacturers Association and printed at Ace Data Prinexcel Private Limited, 3/304 F, (SF No. 676/4B), Kulathur Road, Off NH 47 Bye Pass Road, Neelambur, Coimbatore 641062 and published at Indian Wind Turbine Manufacturers Association, Fourth Floor, Samson Towers, No. 403 L, Pantheon Road, Egmore, Chennai 600 008.

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Vide No. TNENG/2015/60605

June - July 2018
Date of Publishing: 20.07.2018