Indian Wind Power

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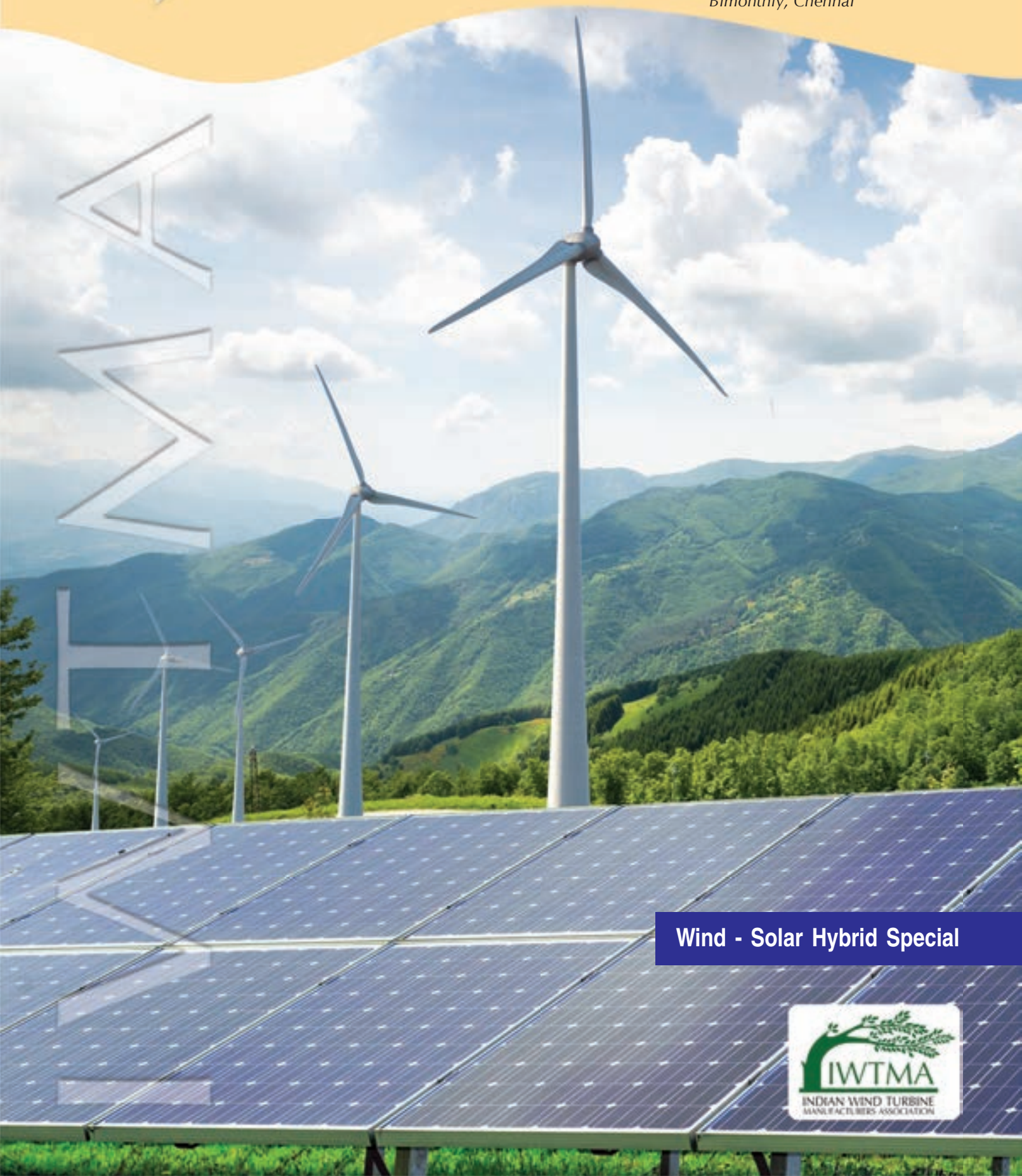

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IWTMA
INDIAN WIND TURBINE MANUFACTURERS ASSOCIATION

Indian Wind Power

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Volume: 4 Issue: 5 December 2018 - January 2019

Contents

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From the Desk of the Chairman - IWTMA

Dear Readers,

The Governments' commitment to achieve target of 175 GW by 2022 and scaling up renewables as mainstream energy source, is evidenced in various policy actions for wind, solar, wind solar hybrid and offshore wind. However, there is an immediate need to synchronize policy amendments and transition, on-ground challenges and efforts of all stakeholders including the state and central governments to enable this target. The prolonged transition coupled with non-availability of grid, land infrastructure and delayed payments from utilities, has further stagnated the growth of renewable energy.

The rear mirror view of 2018 is characterized by certainty of volume growth through the bidding process, traction in wind-solar hybrid and off-shore. On the flip side, it is also reflective of low-wind installations due to the policy transition and uncertainty, unviable tariffs and job losses. The wind industry, which has created over 2 million jobs so far, and is an epitome of the 'Make in India' vision, is severely impacted. Over 4,000 SMEs producing wind turbine components across the value chain are suffering as installations are on a stand-still. State procurement of wind power has come to a virtual halt and many restrictions on wheeling and banking are not allowing Open Access transaction. The industry currently is dependent on central procurement through Solar Energy Corporation of India (SECI) which is largely concentrated in to the high wind States of Gujarat and Tamil Nadu.

However, amidst the short-term challenges of the transition period, the wind industry is poised to grow exponentially on the back of already auctioned capacity of ~12,000 MW and ~10,000 MW auctions in the pipeline. FY20 onwards the industry outlook is extremely promising as the Indian wind industry will be a 8,000 to 10,000 MW market annually.

The industry welcomes the announcement of Gujarat Government land allotment policy for wind/solar/wind solar hybrid park for a potential of 30 GW. Gujarat will become the growth market in future. Unfortunately, the unavailability of land to the winners of the SECI bid for interstate transaction may delay commissioning of SECI - III, IV and V projects.

The upper cap (pricing-cap) on tariffs has further catapulted the stressed market conditions owing to declining tariffs and shift to reverse auctions. These factors put together are posing a real challenge to the industry making it unviable for a meaningful Internal Rate of Return (IRR) for investors.

The time has come for all stakeholders to come together to achieve the target with meaningful tariffs and ensure utilization of 10 GW manufacturing capacity in the country and a localization of over 75%.

The wind tariffs are stabilizing as reflected in the SECI VI auctions. I am confident, with a collaborative approach, all stakeholders will benefit from the growth opportunities in the long term and by harnessing wind power.

The National Wind-Solar Hybrid policy issued last year by the Ministry of New and Renewable Energy (MNRE) provide a framework for promoting large grid connected wind-solar PV hybrid systems for efficient utilization of transmission infrastructure and land.

The first auction of 1.25 GW by SECI of ISTS connected Wind-Solar Hybrid tender attracted a highly competitive tariff of INR.2.67 per unit. Recently, the Government of Andhra Pradesh also announced its Wind-Solar Hybrid policy.

The industry is confident and extremely optimistic about the Wind-Solar hybrid opportunity. Aligned to the industry enthusiasm on this topic, the focus of the current issue of the magazine is Wind-Solar Hybrid with articles from experts and industry practitioners.

I wish the readers a 'powerful' and good year ahead.

Happy reading!

With regards,

Tulsi Tanti
Chairman

India's First Wind–Solar Hybrid Project by Hero Future Energies

Sunil Jain, Chief Executive and Executive Director
Hero Future Energies

Introduction

A wind–solar hybrid project was developed by Hero Future Energies at Kavithal village in Raichur District in Karnataka state by adding 28.8MW solar PV site to an existing 50MW wind farm. This is the India's first large-scale wind–solar hybrid project.

Concept of the Project

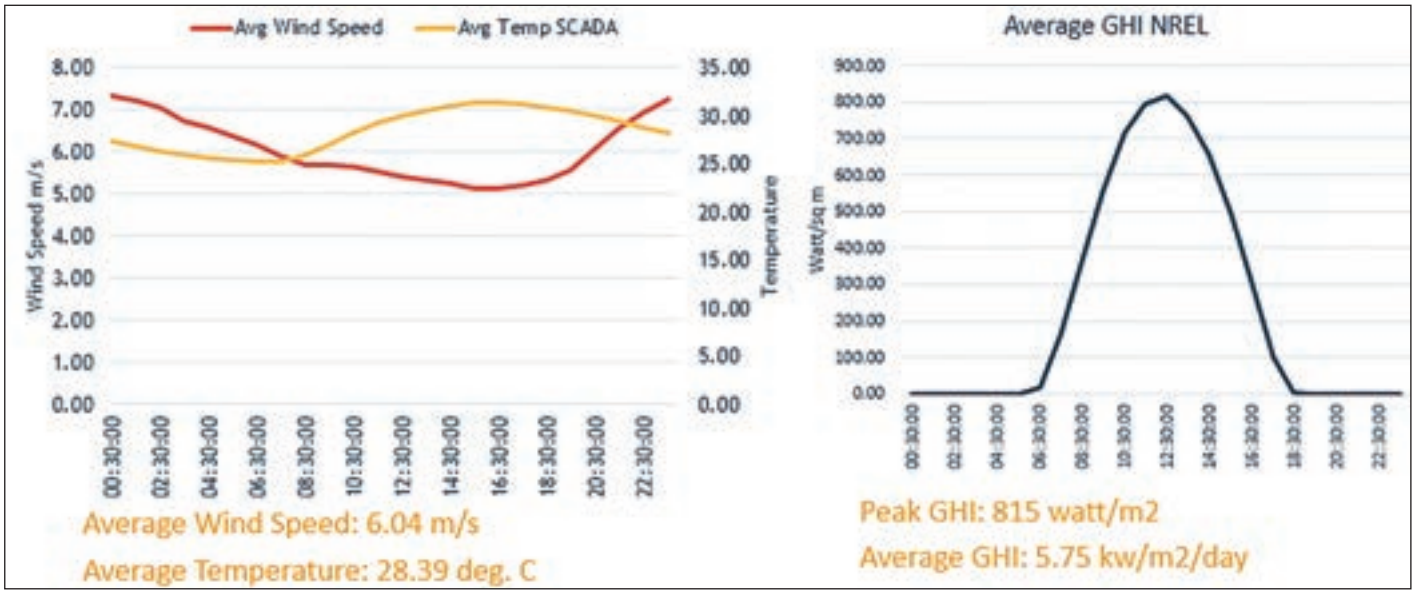
To design wind–solar hybrid system as a first step we studied the available renewable resources and diurnal & temporal consumption load of the said plant. By fixing the average availability of wind speed and analysing wind data of last 10 years, the tentative generation was plotted for a year. We conducted data sampling on small time sample, assuming that wind availability varies from 23% to 30% dependent on a specific area and the type of machine. But this information alone was not enough to plot the consumption load pattern for that area, therefore, another easily available and complementary resource, solar came into play. By referring to historical solar irradiance data for the last 10 years during the same period, we calculated solar generation pattern and by superimposing and optimising the yield, optimum capacities for both the plants were finally calculated.

Graph 1 indicates sample pattern for wind speed & irradiance for particular location & Graph 2 indicates superimposed power output from both sources using wind speed and irradiance data.

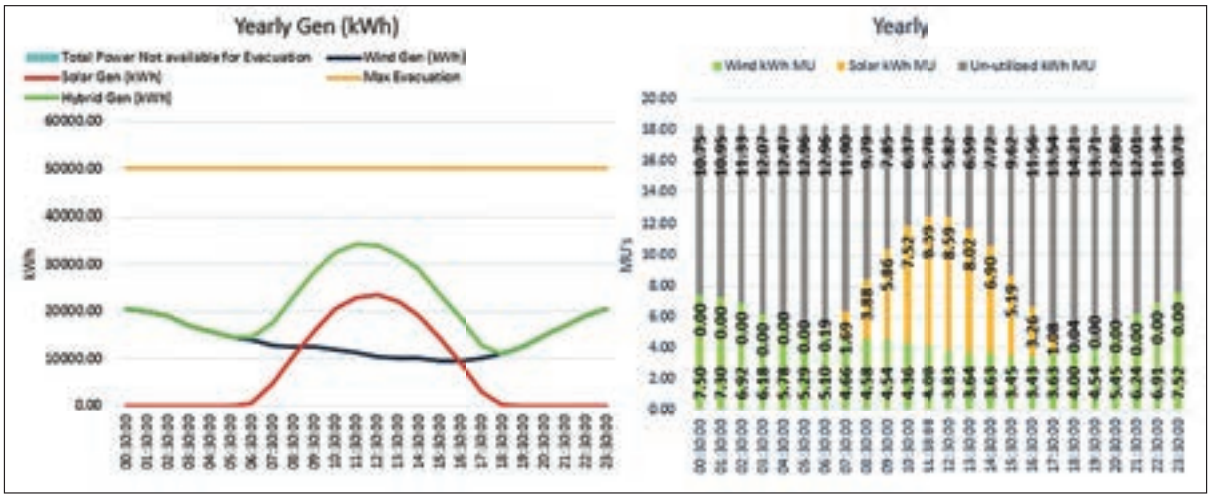
The consolidated combined power sufficed 50% to 60% of the consumption requirement and still could not come out of infirm power. Thus evolved the need to introduce the third element. In recent times battery storage technology has developed substantially and it qualified as one of the best option to fill this gap in providing power in case of non-availability of any renewable resources thus contribute in converting infirm power to firm power evacuation.

By stacking two battery systems in parallel, one could get charged during excess energy generation from renewable sources and other stack remains available to support the fulfilment of load requirement thus making the grid more stable as compared to single renewable energy source.

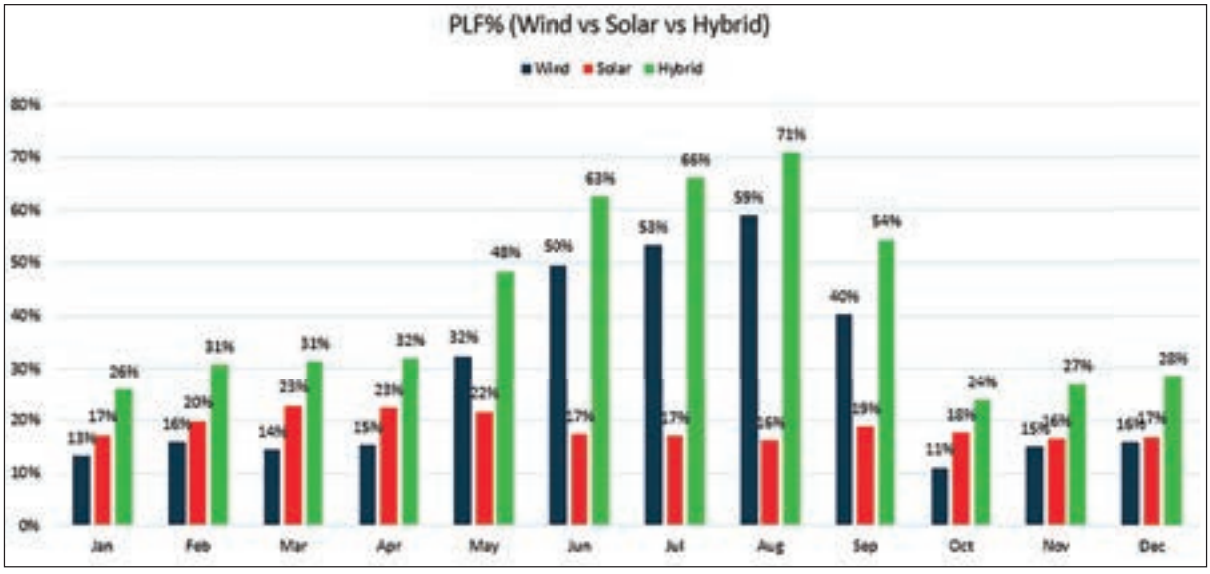
Graph 3 indicates the Plant Load Factor for hybrid resources (wind & solar) reaching to maximum of 71% in a month as compared to individual resources as wind 59% & solar 16%. Graphs 4 & 5 indicate space for including battery storage and evacuation of excess power in case both wind & solar resources are not able to evacuate due to power evacuation limits.



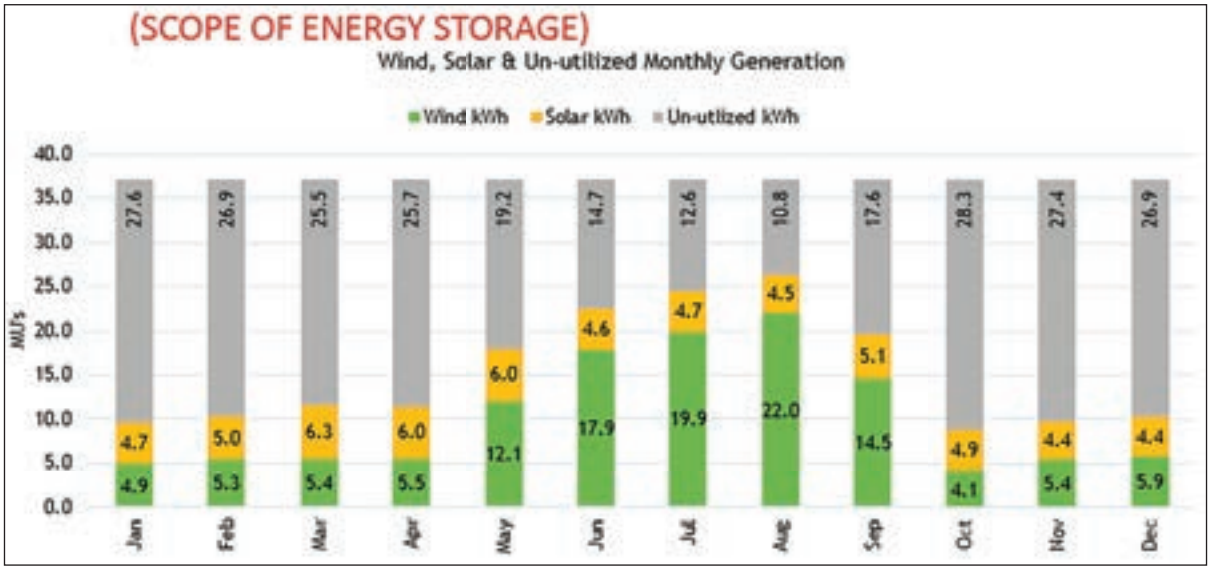
Graph 1: Sample Pattern for Wind Speed & Irradiance for Particular Location



Graph 2: Superimposed Power Output from Wind and Solar Sources



Graph 3: Plant Load Factor for Wind v/s Solar v/s Hybrid



Graph 4: Wind, Solar and Utilized Monthly Generation

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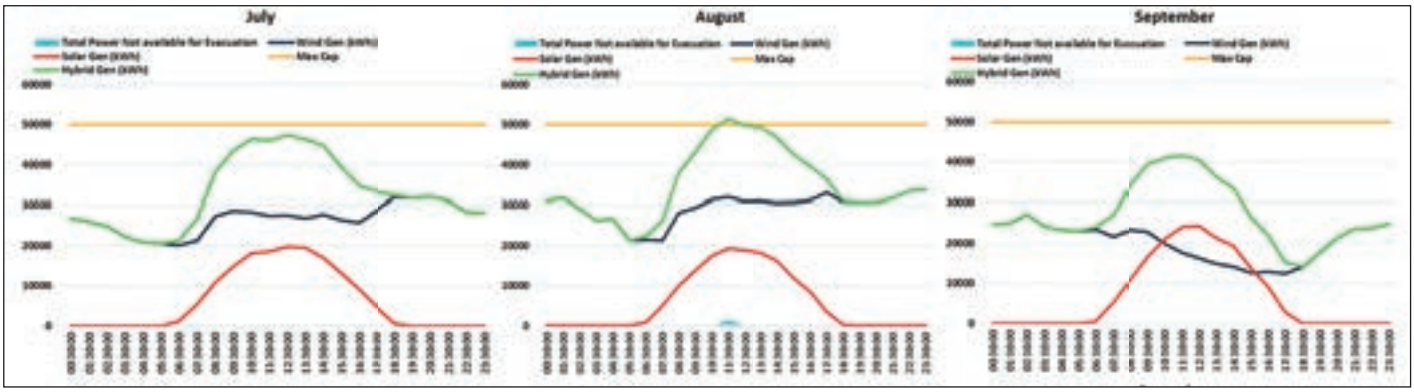

Graph 5: Wind, Solar and Hybrid Generation and Total Power not available for Evacuation

The real challenge in this entire process was to combine all resources at one node and automatization of logical decision to choose the right generation resources to fulfil the need of consumption load and charging of battery. The solution we arrived at was simple in nature. Generation system generates the power by taking the reference of grid so all parameters of AC remains unaltered. Therefore, synchronisation between different sources was not the real challenge, but distribution of power in correct ratio by controlling the inverters was the key to this technology.

The "EMS" i.e. Energy Management System was introduced to control the amount flow and direction of power, we would be able to have reliable resource of renewable energy which can meet demands consistently. This system will act as a master controller and govern all generation sources like wind/solar/batteries. Algorithm of EMS will decide which generator system will be allowed to pump the adequate amount of power in respect to available resources and cost of the power. It can also regulate and divert excess power to charge the battery systems for supporting the peak load conditions.

Module Performance

An unsung benefit of hybrid systems is that by choosing a location with naturally high wind resources, the temperature of the solar modules is also reduced by the breeze, thus increasing the PV generation. Year-round lower temperatures on the solar panels from the wind also reduces the rate of degradation in the modules.

Evacuation Infrastructure

The projects evacuation capacity for this hybrid project, which was at 50MW for wind power project alone, remains the same at 50MW since the primary aim is to address grid-integration concerns around variable power coming from renewable energy.

Cost Savings Due to Hybrid

Not only does the hybrid system share the transmission infrastructure, but the operations are also shared by the same teams, thereby reducing costs even further.

However, operations and maintenance (O&M) teams are different since the solar system requires manual, water-based cleaning twice a month, in this extremely dusty region. The barren land is naturally dusty, but there are two types of dust that impact solar. Dry dust, as in the arid, desert state of Rajasthan, can be easily wiped off or blown off by the wind, but dust in humid conditions tends to stick the panels, which can impact irradiation on the panels and cause soiling in the long-term.

The Wind–Solar Hybrid Farm Group Captive Project

We were able to go ahead with this pioneering Wind–Solar hybrid project, because it is a group captive project, where the off-takers are a number of unnamed private companies based in the state of Karnataka. This gave us the freedom to deliver the pricing on its own terms, while of course delivering huge cost savings to the consumers as compared to normal grid electricity.

Our one of the philosophies is to be the first in the market with new technologies and the firm is constantly looking at how to innovate.

The next push in renewables creativity and R&D will be retrofitting existing sites and working out how to extract more energy from them.

Wind–Solar Hybrid Technology

At Kavithal village, both the wind and solar power plants were developed by Hero Future Energies and built by EPC contractor Siemens Gamesa. The wind project uses Siemens Gamesa turbines and inverters, while the solar PV project uses Gamesa inverters and 320/325W modules from China-based manufacturer Suntech. Cables were sourced from Hyderabad-based firm KEC International, and steel for mounting structures was sourced locally to the company's specifications.

Pricing

There is a need to clear the uncertainty on how to price such technology combinations. Without adequate pricing, project developers would not be able to sell their power to a distribution company (Discom) or partake in an auction where prices are the cornerstone of the bidding.

To determine the pricing of hybrid power, a highly advanced modern technology and software has to be used taking an assumption of how much solar and wind will be generated separately, before taking a weighted average of the generation and price.

Here the beauty is that the price for both gets lowered since the infrastructure is common. The project is using the same evacuation and same substation etc.

Indeed, due to the existing wind site, almost all the necessary infrastructure for the solar plant was already available, and the project only required a few enhancements, such as updating the inverter technologies. Some extra land had to be purchased for the solar system, which is spread across 65 hectares, but we were already familiar with the location, the landscape and the local authorities, which made the process easier than developing a standard PV project from scratch.

Typical Landscape in Karnataka

If one flies from Hyderabad in Telangana towards Karnataka, several individual solar and wind projects - as well as the occasional thermal power plant - could be seen marking the flat plains of this part of central, southern India. Apart from green pockets of lush agriculture, formed through irrigation, the land is sparse, barren and sunburnt with temperatures regularly hovering around 40 degrees celsius during summer.

Karnataka itself is also particularly affable to renewable energy, because there is plenty of land, with strong winds and irradiation. It will become the next big state for wind capacity after Tamil Nadu, and it is already a leading state for solar.

Erecting Transmission Lines - Problems in Land Acquisition

The toughest thing about doing renewables in India is land. While erecting 20 km transmission line we have to encounter a large number of people. Indian land records are not digitized so one has to deal with both a private surveyor and a government surveyor and plots of land that are suitable for a project can be owned by hundreds of different people. Though the land is only 5-10% of our cost, but 95% of problems lies with land.

Thus, even though we had to purchase some extra land for the project, the hybrid element actually reduced the land requirement, particularly with transmission and this is the biggest benefit of hybrids.

Energy Storage Lurking

The third point, energy storage is a couple of years away from entering the mainstream in India.

In its solar wind hybrid policy, Ministry of New and Renewable Energy (MNRE) had targeted 10GW by 2022. Following this, the state of Andhra Pradesh released a draft document outlining its plans for 3GW of wind and solar hybrid projects by 2019/20. But while policy action stuttered since these announcements, the next stage after wind and solar hybrids, which introduces a third pillar in the form of energy storage, seems to be progressing with its own momentum.

Andhra Pradesh authorities are already planning to tender a project involving 120MW of solar, 40MW of wind and 20-40MWh of storage. Meanwhile, Kerala's Agency for Non-Conventional Energy and Rural Technology (ANERT), is working on an experimental, technology demo to include 3MW of solar, 4MW of wind, and battery storage.

We believe that large-scale coupling with energy storage will proliferate in the next two to three years. While price remains a problem, we are already using storage to benefit its own plants but at a very small scale - carrying out studies with small batteries.

We are looking at future smoothing of the grid using storage and also releasing stored energy at peak times on the grid.

A View of the Wind–Solar Hybrid Project

Future of India's Wind–Solar Hybrid

Looking at how India can drive wind–solar hybrids into the mainstream, we can say that we should start a narrative where we should ask the government as the industry to come up with wind–solar hybrid tenders.

Existing solar park projects, where the government has been monitoring progress closely will be the most suitable locations to add wind, while fresh tenders for new wind and solar together will be easier to bid out and get a price for both sources together from scratch.

There are two main benefits of wind–solar hybrids. The first one is, obviously, there is better and more efficient use of the land and transmission infrastructure, which reduces the capital cost by something like 5-7% and that is parked through and results in overall lower tariff. So the Discoms and the power purchaser should actually be keen on hybrid projects like this.

The second one is that the hybrid power project also makes the power output a little bit more reliable than a standalone solar or standalone wind project so that again from a Discom's point of view or from a transmission grid stability point of view should be actually better for the entire system.

There are many benefits of hybrid renewables and a number of other players may join this area. We are seeing a good future of wind–solar hybrids farms with the release of government policy in this regard.

Wind Solar Hybrid – The Technological Advancement in Renewable Energy Sector

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Introduction

India has an ambitious plan of 175GW renewables by 2022, including 40 GW of rooftop solar, 60 GW of grid-scale solar and 60 GW of wind. During the first half of the year 2018, India installed 4.9 GW of solar power and secured the position of the second largest solar market in the world. The country will soon become the global solar hub with some of the largest solar parks in the world as Government has approved plans for 14 solar parks. According to a recent report by a consultancy firm Bridge to India, new installations during the year will reach 14GW, which is about 50% more than the capacity added last year. The wind generation capacity in India as of 31st December 2018 was 35138GW, making India fourth largest installed wind power capacity in the world. We expect the capacity of wind energy to reach 60 GW over the next two years. India is quickly increasing its share of renewable energy sources but still depends on coal, oil and natural gas and the related carbon emissions for 80% of its electricity. RE industry in India has shown the ability to scale up rapidly while delivering significantly lower cost. So the main challenge in meeting the National Renewable Energy targets is the ability of the Indian electric grid to integrate these variable resources.

National Wind–Solar Hybrid Policy

To accelerate the pace of RE activity, Ministry of New and Renewable Energy on 14th May 2018 has announced National Wind–Solar Hybrid Policy two years after the draft was released in 2016. Additionally, it granted approval to auction 2.5 GW worth of wind–solar hybrid projects. The objective of this policy is to provide a comprehensive framework for the promotion of large grid connected wind–solar PV hybrid system for optimal and efficient utilization of transmission infrastructure and land. Under the policy, the government will extend all fiscal and financial incentives available to wind and solar power projects to hybrid projects. It will also support technology development projects in the field.

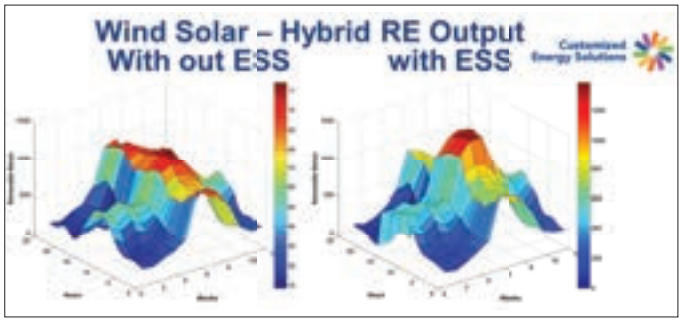
The best part of the policy is that it encourages to combine all types of energy storage technologies to the hybrid project for reducing the variability of RE generation output and ensuring availability of firm power. Implementation of storage system would facilitate the integration of renewable energy generation in an efficient manner, whereby reduces DSM penalty charges borne by RE developers.

On the technology front, the policy provides for the integration of both the energy sources i.e. wind and solar at AC as well as DC level. It also provides for flexibility in the share of wind and solar components in the hybrid project, subject to the condition that, rated power capacity of one resource be at least 25% of the rated power capacity of other resources for it to be recognized hybrid project. With significant capacity additions in renewables in recent years and with hybrid policy aiming at better utilization of resources, it is envisaged that the policy will open-up a new area for availability of renewable power at competitive prices along with reduced variability.

RE Projects

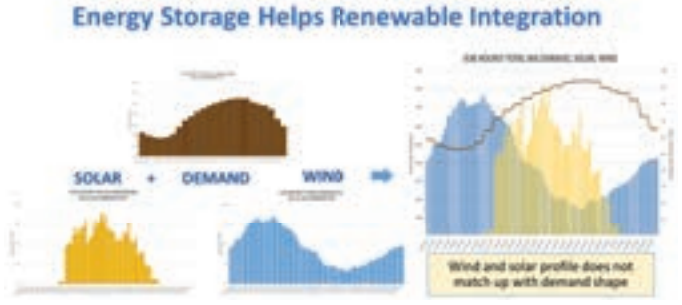
As per the projections by the Central Electricity Authority (CEA) in its National Electricity Plan (NEP), solar and wind capacity combined could account for over 25% of the installed capacity in the grid by 2022 if the 160 GW target is achieved. Experts believe that India has an ideal market for hybrid projects, considering that many states are rich in both wind and solar energy resources. Gujarat, Tamil Nadu, Maharashtra, Karnataka and Andhra Pradesh have large capacities of both wind and solar power projects.

One of the key constraints in the development of solar and wind projects is access to land and evacuation infrastructure. By co-locating wind and solar projects, the capacity utilization of power evacuation increases. These two modules make up around 25% of the cost for a renewable energy plant. Using hybrid projects, the wind and solar modules will feed power into the same transmission lines, allowing firms to have almost twice the capacity on each site and to make better returns on their investments. Hybrid RE projects can also ensure the greater contribution of RE to meet the peak load as shown in the charts below.



Why Storage

Applications for energy storage related to renewable energy include RE smoothing and RE firming. RE smoothing addresses the short duration variability in output of the wind or solar energy (typically within 15 - 30 minutes). RE Firming is shifting of renewable energy output to times where grid requires it most (typically 2- 4 hours). Examples of RE firming include shifting part of solar PV output during 11 AM - 2 PM to 6 PM - 9 PM to meet evening peak or shifting peak and wind output from early morning hours to 7 AM to 10 AM to meet morning ramp up on the grid. Apart from this energy storage can also be used to provide reactive power support to improve renewable integration particularly on weaker distribution feeders.



India Picture

The immediate requirement from the transmission sector is to meet the demand from the renewable energy sector. At the same time with the rise in generation from RE sources and consequently more demand for the transmissions sector. The government has identified dedicated transmission corridors and substations with the capacity to transmit about 18,500 MW electricity from wind and solar plants in western and southern regions.

As part of the implementation of the first phase of the scheme for setting up of 23GW Solar PV Projects in Leh & Kargil regions in Jammu & Kashmir, Solar Energy Corporation of India Ltd has released the RFS for setting up of 2500 MW in Kargil district and 5000 MW in Leh district. However, as per sources the work on these projects has not been started yet due to unavailability of land and infrastructure requirement.

The first solar–wind hybrid plant in India was commissioned in India in 2018 in Karnataka by Hero Future Energy (HFE). The plant at Kavithal, Raichur District, which included an existing 50MW wind farm, now has a neighboring 28.8MW solar PV site to form a hybrid system. When the wind power plant at Karnataka was installed earlier, power supply to the grid was for only 8 hours a day, during the evening alone. The entire evacuation system was idle from the morning and onward. Thus co-location of a solar plant was done to effectively use solar power during the day, and wind power during the night. As opposed to the 8 hours before, power supply of 18 hours a day post commissioning of the solar–wind hybrid plant. The Plant Load Factor (PLF) of the site has gone up from 28% to 48% post the co-location of solar plant.

Solar Energy Corporation of India (SECI) is planning to develop its own renewable energy projects at the Indian archipelago of Lakshadweep, with an eye on coupling the projects with battery energy storage. The aim is to power the inhabited islands in Lakshadweep partly or wholly through renewable energy sources. A tender document for the design, engineering, supply, construction, erection, testing and commissioning of the projects including 10 years of operations and maintenance (O&M) will be available from 31st January. Similarly it also invited bids for Design, Engineering, Supply, Construction, Erection, Testing & Commissioning of 160 MW Solar–Wind Hybrid Power Plant with BESS at Ramagiri, Anantapur district, Andhra Pradesh, India.

Energy Storage System Projects around the World

Across the world, in the past 10 years large hybrid projects are done which includes a 98MW wind power generation plant located in Belington by AES Laurel Mountain with 8MWh grid energy storage solution. ECoult - Australia (Kings Island) uses a 3MW/1.6MWh Ultra Battery Storage system. French renewable energy developer Neoen won approval in early 2018 for its third wind farm and battery storage project, near Cairns in far north Queensland. In 2017, it switched on the 100MW/129MWh Tesla battery that sits next to the 309MW Hornsdale wind farm in South Australia.

At 100MW/129MWh, the Hornsdale Power Reserve is the largest lithium-ion battery in the world

Seven major solar-plus-storage projects on Oahu, Maui and Hawaii islands in US, representing the largest infusion of renewable energy in state history, are now in contract negotiations between developers and the Hawaiian Electric Companies, with 1,048 megawatt-hours (MWh) of storage.

Similarly, Fluence will build a 40-MW/160-MWh lithium-ion battery facility in Fallbrook, CA which is expected to be completed by March 2021. While Renewable Energy Systems (RES) America will build a 30-MW/120-MWh lithium-ion battery storage facility in San Diego, California by December 2019.

One of the concerns about adding storage to solar and wind projects has been increased cost. But given the advancement in storage technologies, the levelized costs are falling vary rapidly. In 2017, TESLA had commissioned a project in Hawaii with levelized cost of $0.139/kWh (i.e. ~ INR 8 Rs/kWh) for Kauai Island Utility Cooperative. In 2018, AES deployed a similar project with PPA for $ 0.108/kWh (i.e. INR 7.45/kWh) at the same island. Now, for 2020-21 delivery, we have witnessed some of the largest hybrid projects promising levelized costs of under $0.04/kWh (i.e. under INR 3/kWh). So, it is high time that India also starts deploying large scale wind – solar hybrid projects with storage and not just wait to see other countries take lead in this area.

Conclusion

Given the scale of RE deployments in India and the challenges for grid infrastructure, India can also be home to some of the largest hybrid projects by 2020, if policy makers can address some of the pending policy changes such as launch of National Energy Storage Mission before the elections in 2019. Minister of Power and New & Renewable Energy Shri R. K. Singh has taken a very proactive view on the opportunity of energy storage in India. Under the leadership of MNRE Secretary, Shri. Anand Kumar, expert committee has drafted the National Energy Storage Mission, which is expected to get launched this month after final cabinet approval. The mission will cover aspects related to renewable integration at the transmission level, distributed renewable integration at the distribution level, the role of storage for energy access and microgrids as well as the EV charging infrastructure as well as battery requirements. Once this mission document is in place it will act as a guiding document for scaling up energy storage and hybrid projects in India.

Snippets on Wind Power

NITI Aayog Pitches for Bringing Oil, Coal, Power under GST

NITI Aayog has pitched for bringing oil, natural gas, electricity and coal under GST (goods and services tax), a move that would allow input credit to make Indian industry globally more competitive and reduce energy bill for consumers. The 'Strategy for New India @75', a vision document released by the government think-tank on 19th December 2018, also establishes a link between tax and subsidy regimes for energy in India and the goal for reducing the economy's carbon footprint. As a way out, the paper suggests same GST rate for all forms of energy to enable a level playing field and providing all form of subsidies as functional subsidies to end-consumers so that they choose the most suitable and economical form of energy.

Source: TNN, December 20, 2018

Costa Rica Hits Renewable Energy Mark for Fourth Year in a Row

Costa Rica has generated more than 98 per cent of its power through renewable sources for the fourth year in a row, the state energy body has said. In 2018, just 1.44 per cent of the central American country's electricity came from fossil fuel plants, the Costa Rican Electricity Institute said in a statement on 20th December 2018. It is an example for the region and the world. River water is the main source of energy, providing 73.87 percent of the country's needs, followed by wind (15.6 per cent) and geothermal energy from its volcanos (8.38 per cent). Costa Rica avoided using its fossil fuels plants in 300 days during 2018; the last instance came on May 17.

Source: PTI, December 21, 2018

Gujarat Government suggests Wind Park to accommodate Central Developers

Of the 7,000 MW of wind projects auctioned by Seci last year, 3,500 MW are expected to come up in Gujarat. The Gujarat government is considering a proposal to give land for centrally-sanctioned wind projects on the condition that the winning developers set up projects at the site decided by the state government – a sort of wind park. Though wind projects in Gujarat are mostly located in Kutch, they can also be found outside this region in places where wind speeds are high enough to generate energy.

Source: ET Bureau, January 18, 2019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Wind–Solar Hybrid: A Perspective

Abhilakh Singh, General Manager
Indian Renewable Energy Development Agency Limited, New Delhi

In its pursuit of achieving renewable energy target of 175 GW India is continuously evolving the way it used to meet its energy requirement. Supported with conducive policy, global price crash of Solar PV modules and improved efficiency of Wind turbines and solar PV modules, generation cost of these two renewable energy sources have achieved grid parity.

One of the hurdles continuously cited in the adoption of renewable energy is the intermittency of power produced by these sources. A way forward is therefore combining different sources of renewable energy to reduce fluctuations and maintain a uniform supply. Recent development in this regard has been wind–solar hybrid with or without battery storage. Existing infrastructure (like transmission lines, etc.) which remains idle most of the time can be used more efficiently with the hybrid system. According to the policy, a wind–solar plant will be recognised as hybrid plant if the rated power capacity of one resource is at least 25% of the rated power capacity of other resource, which will be considered for benefits under the hybrid power plant umbrella.

It has been observed that solar and wind energy complement each other i.e., when there is lack of one of the resources often the other one is available. For example, wind speed is high during monsoon while due to cloud cover solar energy generation is low, also during night time wind speed is high. So, wind–solar hybrid is slated to decrease fluctuations in the energy produced by either one of the sources when taken in isolation.

Though a solar–wind hybrid may be a better proposition for any DISCOM, integration at generating units may be the complicated part and this is one of the reasons developers in India are taking time in bidding for hybrid projects. This is evident from the fact that SECI has to extend the bid few times, revising the bidding capacity and the ceiling price. Still, the final bid got undersubscribed by 150 MW and therefore only 80% of the 1050 MW subscribed, i.e., 840 MW was awarded.

With the multiple benefits there are also certain limitations surrounding the hybrid establishments. Since, both the wind turbines and the solar modules are placed along with year-round time-based generation considering the shadow losses in the PV modules and wake loss due to wind flow pattern. Apart from it, the transmission efficiency should not reduce the overall efficiency of the plant.

At times there may be both solar and wind energy availability at peak, under those circumstances both the solar module and wind turbine will be working at full capacity, in such cases proper measures should be taken to protect the transmission system to avoid any system breakdown. Though adding another component of battery storage can come handy in such cases, it can be used for storing energy in case generation is high and to absorb fluctuations in supply.

With application of reverse bidding processes, energy cost from renewable sources mainly from solar and wind has reduced substantially. So, it seems that reverse bidding is the most efficient and competitive way for solar–wind hybrid projects as well. Still, strict monitoring of ongoing projects should be done so that we get a clear picture of impact of various factors on each of the resources and also the overall impact on the system and slowly but steadily move towards renewable energy sufficiency.

Different independent reports claim increase of CUF to 35% to 40% on an average for these power plants, though these cannot be substantiated at present in absence of data. There have been many discussions in this regards where some reports claim 50-50 ratio of wind–solar capacity will be best while others claim the ratio to be 60-40 will be fine, but these reports also cannot be endorsed in absence of data. Mostly, these reports are made for a specific area with some fixed conditions/assumptions. Therefore, impact of different factors on each of the sources should be carefully studied before taking any decision for such power plants.

Furthermore, the hybrid establishments, when made in the existing solar or wind power plant establishments, their efficiency increases and since any new transmission line is not required to be added, cost and complexity reduces by significant margin. However, there remains uncertainty regarding the cost of project because of losses and their impact on total energy generation and hence price of energy for which not many developers are enthusiastic about in the recent bids and they want tariff ceiling to go high.

To develop hybrids as a new trend in renewable energy then initially, we may to go with little smaller capacity and keep them under observation, get experience and then bid for higher capacity with more certainty on cost of project. Apart from this, if specific areas are selected by the government and transmission facilities are provided in those areas, the way it is done for solar parks then it will serve as integrated area for the development of the sector with all the required infrastructure facilities.

Wind–Solar Hybrid – A Brief Perspective

Narendra Somoshi

Rahul Jain

Renewable energy is gaining its ground globally, and more so in India, with both solar and wind getting economical than conventional sources of power. However, one argument which still impedes upsurge of renewable energy, is its 'Infirm Nature'. Various solutions have been pursued by countries globally, viz. augmenting its transmission networks, introducing smart grids to handle variation in generation to match load requirements, investing heavily in grid level and/or project level storage systems. Another effective way, which surprisingly hasn't picked up globally till now but is poised to flood Indian market, is Hybrid Renewable Energy Systems or popularly known as HRES. Simplistically put, a Hybrid renewable energy system usually consist of two or more renewable energy sources utilizing common infrastructure together to provide increased system efficiency as well as greater balance in energy supply. The most common of them are the Wind Solar Hybrid projects that may also be coupled with storage to provide a stable power output.

Wind and Solar complement each other in their generation curves mitigating, to a certain extent, variability due to weather inputs as peak operating times for wind and solar systems occur at different times of the day and year.

Integration Alternatives – Where and Why?

As discussed above, hybrid is all about integrating various sources to optimize overall efficiency of the project. But the key question is where to integrate. While simplest integration can happen at the individual substation level, a true hybrid can happen by integrating and managing the power output right at the DC level. While the Wind–Solar Hybrid Policy of the Ministry of New and Renewable Energy is silent on specific integration issues, Gujarat Wind–Solar Hybrid Policy 2018 talks about both AC and DC integration. However, here also DC integration is allowed only in case of new projects. Andhra Pradesh is also working on its own Hybrid policy, the contours of which is yet to be known.

However, it is very important to understand the objective before deciding on where and how to integrate. While not much regulatory intervention is required for AC integration, right framework is still not there for a true hybrid DC integrated project.

Integration at	Pros	Cons
DC Level. i.e. Turbine/ Inverter level	• Most economical due to optimized usage of common infrastructure, i.e. Controllers, WTG Transformer, Evacuation network, etc. • More stable output due to granular control	• Crane movement during maintenance • High land cost for Solar • Shadow impact on panels • Regulatory hurdles/Metering issues
33kV i.e. internal transmission line Level	• Relatively easier to construct, monitor and meter • Optimizing EHV evacuation infrastructure	• Higher cost of land • Variation in output is relatively higher
At grid substation level	• Simplest of all • Can be monitored separately	• Obligation on Grid to decide right renewable mix to obtain actual benefits of hybridisation

Case Study – Site in Gujarat

To assess the impact of hybridization of renewable energy, we chose a site in Gujarat (good from both wind resource as well as solar resource perspective). The following were the results:

a. **Stable Output –** As expected, a 50:50 combination resulted in a much more stable generation curve as against standalone wind or solar.

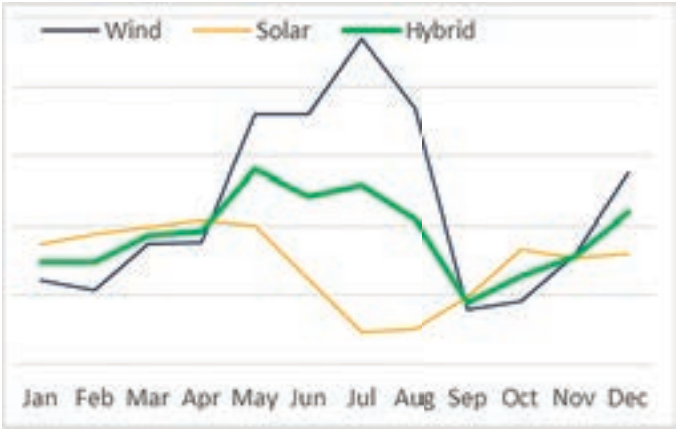


Chart 1: Generation Curves with a Mix of 50% Wind and 50% Solar

This not only provides far more cushion while scheduling the generation but also optimize the evacuation network far more efficiently. We can see the benefit of the same in Chart 2 below.

b. **Optimum Utilization of Evacuation Infrastructure** – In the above analysis, let's now include the impact of evacuation constraints. Especially for wind projects, while Gujarat still enjoys relatively consistent weather as compared to states like Tamil Nadu or Karnataka, yet there are definite seasonal as well as day peaks.

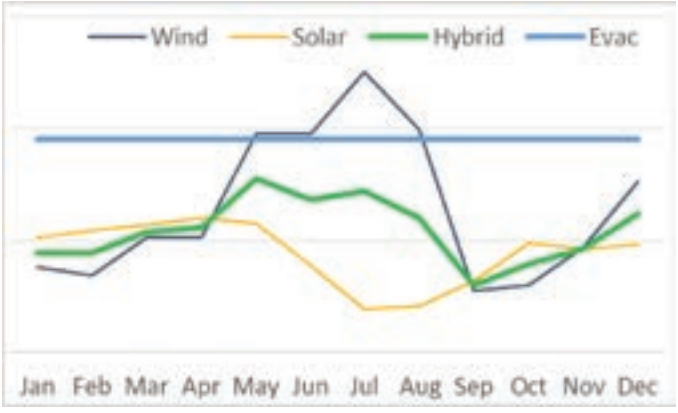


Chart 2: Hybrid project will typically be able to pump more units in a constrained evacuation environment

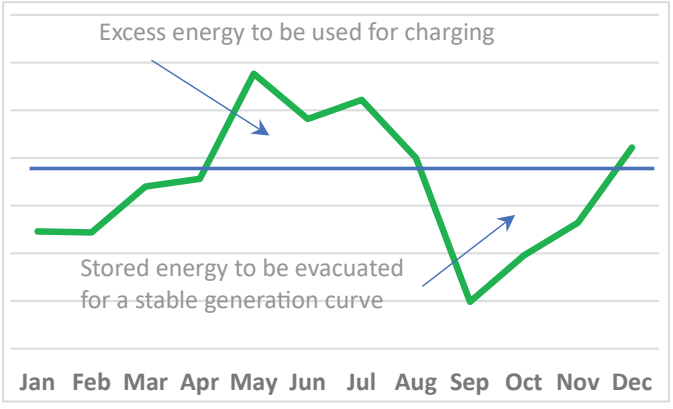
While there will still be some day-wide clipping in a hybrid project, overall it will be able to pump much more units into the grid, i.e. will be able to utilize the evacuation infrastructure optimally.

c. **Other Synergies** – In addition to other technical benefits, there are good amount of synergies available (if the project is conceptualized correctly and designed accordingly). With sharing of evacuation infrastructure, site and management team, there will be apportionment of Capex as well as Operational costs over larger capacities thereby reducing the project cost. However, the site has to be ideal for both wind and solar installation (in terms of wind speed/ solar radiation, land availability, ecosystem availability, etc.) to achieve real benefits of hybridization.

Moving towards Round-the-Clock (RTC) Renewables

While Hybrid does provide relatively stable power output and complementing nature of weather resources, the risk of 'Infirm Nature' still persists. Therefore, eventually where we perceive renewables to compete directly with conventional sources of power, a suitable storage mechanism has to be added to remove any availability concerns. Also, with rapidly reducing cost of storage this is becoming a near reality. World over, renewable projects are competing in capacity tenders guaranteeing a stable capacity which is available round the clock. This not only provides certainty to the generation curve but also opens up additional business opportunities to renewables.

Chart 3: Storage can be added to provide stable generation curve



However, while choosing a hybrid energy system, use case of storage should be selected carefully. While it can be used for both peak smoothing application as well as time shifting applications, these two applications should not be mixed as each require batteries with distinct characteristics.

a. Scheduling & smoothing use case (power application) requires short burst of power delivered. This use-case is more compatible with Frequency Regulation, VAR operation than time shift & curtailment mitigation.

b. Time shifting & curtailment mitigation (energy/capacity application) requires larger energy storage to be delivered/ stored for duration of 2 -3 hours.

c. Clubbing the power application with energy application may lead to various issues:

i. Sizing of the system will be inefficient, since it has to cater to both application, optimum sizing cannot be reached.

ii. Power application require maintaining State of Charge at a level, whereas energy application is generally charge & discharge. This lead to rapid degradation and lower cycle life of the system.

iii. Even within a chemistry, cells are manufactured for a particular optimum C-rate. C-rate of the power application is more than 2C, whereas energy application will be of the order of 0.5C or less.

Indian Scenario – Pipeline and further Regulatory Interventions required

While there have been sporadic efforts of Hybrid opportunities in India – 160MW AP project funded by World Bank and 1200MW tender green-field tender both issued by Solar Energy Corporation of India and the recently issued tender by Maharashtra State Electricity Distribution Company Ltd. However, unfortunately both the allocated tenders have attracted lower than requisite interest from the industry. Some suggestions are listed below to make the opportunities more investable/ bankable:

a. Clear regulations on various integration levels (including DC integration) – Metering mechanism, Renewable Purchase Obligation accounting, Pooling mechanism, etc.

b. State level land use to be permitted for Hybrid projects as well.

c. There may be separate tenders for hybrid including storage with a criteria of stable generation curve (may be within a specific band).

d. Last but not the least, tendering authorities should understand that while there are savings due to cost synergies, there will be additional losses due to lower resource areas. A simple tariff bid at the project level may not be the right incentive. Savings at the transmission level need to be factored in as well.

Snippets on Wind Power

Renewable Energy Generation Obligation- Reduction Recommended

Electricity Act 2003 - Amendments 2018 was placed before the Parliament of India on 19.12.2018.

The Standing Committee on Energy (Chairperson: Mr. Kirit Somaiya) submitted its report on the Electricity (Amendment) Bill, 2014 on May 7, 2015. The Bill was introduced in Lok Sabha on December 19, 2014. The Bill amends the Electricity Act, 2003. Key observations and recommendations of the Committee include: Reducing renewable generation obligation: Due to the intermittent nature of renewable energy, making the renewable energy generation obligation mandatory to a certain percentage may lead to problems. However, there must be a minimum obligation to promote renewable energy. The Committee recommended keeping the renewable generation obligation at five percent instead of the prescribed 10 percent in the Bill.

Wind Speeds decreasing in Past Four Decades

After analyzing data from more than 1,000 weather stations around the world, a team of researchers from the Chinese Academy of Sciences found that 67 percent places had witnessed an extensive decrease in wind power potential over the course of nearly 40 years. They examined the changes of wind surface speeds from 1979 to 2016. Around 30 percent of locations in North America have witnessed a 30 percent drop or more in available hub-height wind power. Sites in Europe were worse, where about 40 percent experienced a similar decline. However, the effect was the most significant in Asia, where around 80 percent of sites on the continent saw a 30 percent drop in wind. The causes are yet to be found.

Delhi: You'll Get ₹ 50/Hour for First 2 Hours of Outages

Discoms will now have to pay power consumers enhanced compensation for outages with Delhi Electricity Regulatory Commission issuing the revised Supply Code 2017. The third amendment will make power distribution companies financially accountable to consumers for their failure to address complaints within the stipulated time period. The compensation policy is in line with the directions issued by Delhi government under Section 108 of the Electricity Act, 2003. According to the new regulation, the power consumers will be paid ₹ 50 per hour for first two hours of unscheduled cut followed thereafter by ₹100 per hour, a government statement said.

Source: TNN, December 20, 2018

Small Wind and Hybrid Technology Solutions for Telecom Towers

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Telecommunications has been recognized as one of the prime support services needed for rapid growth and modernization of various sectors of economy. Day-by-day the applications of telecommunications have drastically increased and are bound to further increase with wider use of smart phones and internet. At the end of March 2017, there were around 1194.58 million telecom consumers in India. Out of this 24.4 million number (2.04%) are wired telecom consumers and 1170.18 million (97.95%) are wireless telecom consumers. The wireless consumers will further increase and hence the requirement of telecom towers would follow. Further, 42% of the consumers are located in rural areas and 58% in urban areas. These telecom towers require continuous power supply for uninterrupted telecom services. Though the power situation in India is approaching to zero peak deficits, but uninterrupted power supply to such telecom towers is an issue in every state of the country. The cost of electricity and diesel for standby power supplies account the majority cost component of these telecom tower operators. Further, use of diesel requires continuous human intervention for topping up the fuel requirement for diesel powered generator which not only increases the manpower cost but also increases the commercial losses and carbon footprints.

For a typical telecom tower, the electricity demand is determined by the number of base transceiver stations (BTS5) housed on it. The electricity requirement per tower ranges from 1 kW to 8.5 kW where more than 80% of these towers have a demand less than 3.5 kW. To ensure 100% power availability, the telecom tower operators use combination of batteries and diesel generator as backup power supplies in addition to the electrical grid. There were more than 4,50,000 telecom towers in India in 2017 and this could require power of around 1575MW at 3.5kW per tower. This is a continuous requirement and bound to increase parallel in urban as well as rural area.

Snapshot of Indian Telecom Sector Electricity Requirement

- Total no. of Telecom Consumers: 1194.58 million
- No. of Wireless Telecom Consumers: 1170.18 million
- No. of Wired Telecom Consumers: 24.4 million
- Percentage of Rural Consumers: 42%
- Percentage of Urban Consumers: 58%
- No. of Telecom Towers: 4.50 Lakhs +
- Total Power Requirement (@3.5-4kW): 1575 - 1700MW

Most of these towers install diesel generators of 10kVA to 15kVA capacity and supplement it with battery banks of 300Ahr to 900Ahr capacities. The diesel generator and battery configurations are decided based on the availability of number of hours of grid electricity, rating of equipments, location of tower, optimal capital and operational cost economics, etc. In case of limited availability of grid power especially in rural area, the battery remains partially charged and cannot cater the requirement. In addition to this, battery the standby diesel generator set is required to be operated for ensuring continuous availability of power supply. Maintenance of such diesel-based systems in rural area is difficult and costly affair than such systems in urban areas where the density of towers and nearby availability of resources like manpower and diesel can be optimally available. Further, these generators require transportation and storage of diesel which is a major problem in rural/remote area besides the problem of noise pollution emanating from the generators.

The required electricity for such telecom towers can be replaced by the renewable energy sources which have the following key advantages over the conventional electricity being supplied through mainly thermal based sources and diesel based standby power supply.

Advantages of RE based Power Supply for Telecom Towers

- Saves from high-running cost of diesel-based generators and recurring diesel cost
- Saves the electricity consumption from the utilities supply

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- Solar PV system gives quality power output of 48 volt DC which can be directly used to storage battery or provide direct power to telecom towers.
- The system can be designed for both off-grid and on-grid applications.
- Efficient and easy installation
- Low gestation period
- Longer life of RE based power generation system close to 20/25 years
- Lower operating costs
- Unmanned operation/lesser O&M manpower required as compared to diesel-based supply

Renewable energy technology options are very specific to the site conditions and availability of resources at site. Some of the RE power generation options suitable for telecom towers are as follows:

- Solar PV based power generation system
- Small wind power generation system
- Wind–Solar Hybrid system
- Fuel Cells

Solar PV based Power Generation System

Solar radiations are abundant and free resource being unutilised. The perennial source of solar energy provides unlimited supply and has no negative impact on the environment. The solar photovoltaic (PV) modules convert solar radiation from the sun into electrical energy in the form of direct current (DC). Converting solar energy into electricity is the answer to the mounting power problems in the rural areas. In India, we have around 5 kWh/m^2/day annual global solar radiation equally spread across the country. Before estimating the feasibility of solar power generation at site, the site specific long-term trend of the solar resources needs to be studied with the help of reliable data sources to estimate annual energy generations. Solar PV based power generation projects require about 10 m^2 shadow free area to generate 1 kW of solar power and generates around 3.5-4.5 units (kWh) per day. Availability of shadow free area to install such solar panels is essential factor for setting up of such projects. Further, in some areas the power generation from solar decreases in monsoon and winter season. Apart from this the grid availability is another important factor which needs to be considered while sizing the system.

Small Wind Power Generation System

Wind energy is another viable option. The Wind turbine generator is designed for optimal operation at wind speed of 10-14 m/s. The turbine generator starts at a cut-in speed of 3-3.5 m/s and generates power at speeds 4.5 m/s and above. 1 kW WTG generates around 3 units (kWhr) per day. In India the best wind speed is available during monsoon from May to September and low wind speed during November to March. The annual national average wind speed considered is 5-6 m/s. Wherever average wind speed is 4.5 m/s and is available, it is also an attractive option to supplement the energy supply. Wind generators can even be installed on telecom tower at a height of 15-20 meter. With suitable modification in tower design, taking into account tower strength and EMI & EMC.

Solar–Wind Hybrid Power Generation System

Hybrid Wind–Solar System for the rural exchanges can make an ideal alternative in areas where wind velocity of 5-6 m/s is available. Solar–wind power generations are clear and non-polluting. Also they complement each other. During the period of bright sunlight the solar energy is utilized for charging the batteries, creating enough energy reserve to be drawn during night, while the wind turbine produce most of the energy during monsoon when solar power generation is minimum. Thus the hybrid combination uses the best of both means and can provide quality, stable power supply for sustainable development in rural areas.

These systems are specifically designed to draw 48 volts DC power output from the solar cells/wind turbines and combine them to charge the storage batteries. The system does require availability of diesel generator, though for much reduced number of hour's operation. It is also designed to give priority to solar and wind power so that operations of generators can be minimized to the extent possible.

Apart from the telecom application for small wind hybrid systems there are many applications like deployed for rural and remote applications for powering to schools, community centres, un-electrified households, defence establishments, agro-industrial activities, coastal applications etc.

Figure 1: A Telecom Tower with Wind–Solar Hybrid Energy System

Grid Connection of Wind Turbines in the 4 to 5 MW Power Range

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R&D Power Converter Manager

Alberto Barcia
R&D Services Manager

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Introduction

The wind sector is globally focusing its efforts on reducing the Levelized Cost of Energy (LCoE) of the technology in order to prove itself as a profitable option in the energy mix regarding electrical generation. Most markets are migrating to tenders for new installed capacity, which in general means lower prices for the generation plants and thus forces projects to reduce both Capex and Opex during their lifetime. In response to this market outlook, OEMs are working hard to develop wind turbines in the 4 to 5MW power range that potentially enable them to reduce the LCoE of the wind farm.

In addition, the increasing penetration of wind power capacity into the grid arises new challenges for the Transmission System Operators (TSO) in order to keep the stability of the transmission system. As a consequence, grid codes around the world are evolving in its requirements towards more demanding conditions such as Fault Ride-Through (FRT) behaviour or harmonic distortion compliance.

Major OEMs are thus developing wind turbines in the 4 to 5MW power range that comply with present and future grid codes. The electrical topology of the wind turbines plays an important role in achieving the technical and economical characteristics demanded by both the markets and the TSOs. As usual, there is no one-for-all solution and the various OEMs have taken their own paths in terms of electrical topology for their wind turbine developments. While Doubly-Fed Induction Generator (DFIG) has been the preferred option for OEMs such as Nordex Energy, Siemens Gamesa or GE in their respective 4MW platforms, the Full Converter (FC) has been chosen by Senvion, Vestas or also alternative platforms of Siemens Gamesa.

DFIG Topology

For the last two decades, DFIG converters have been the most extended topology in the power range of 2.XMW. The low power of the converters and the overall low cost of the drivetrain system have made this topology almost a standard in low power and low voltage wind turbines.

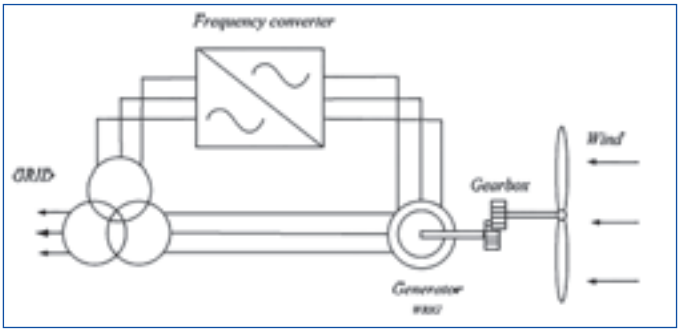

Figure 1: Frequency Converter Diagram

- 30% to 40% of the power goes through the converter.
- Speed window around 40% up and down from synchronous speed.
- Active and reactive power control capability.

In terms of behaviour of a DFIG wind turbine, it has to be considered that the generator has a strong effect on the electrical performance. For grid integration, a profound knowledge of generators is needed, especially due to FRT and power quality. Moreover, FRT events present a nonlinear behaviour in those transients when high currents and voltages appear, due to saturation issues in the generator. This nonlinear behaviour can produce higher currents than expected, thus endangering the fulfilment of the grid code requirements and the converter itself. The current values can reach up to tens of kilo Amperes. To go through these events, nonlinear generator models are needed so as to develop smart control techniques that ensure the fulfilment of balanced and unbalanced FRT events.

Apart from the FRT events, the performance in weak grids is also a recurrent issue when it comes to DFIG wind turbines. A weak grid is understood as a grid with low capacity for electrical energy transmission. It has a low Short Circuit Ratio (SCR) that in a wind farm is the relation between the short circuit capacity of the grid at the common coupling point and the rated power capacity of the wind farm. In such cases, the voltage highly fluctuates with Active and Reactive Power Flow (High dV/dQ & dV/dP - High d(SCR)/dt). Due to this rapid change of voltage, a suitable control loop tuning and grid filter selection are needed.

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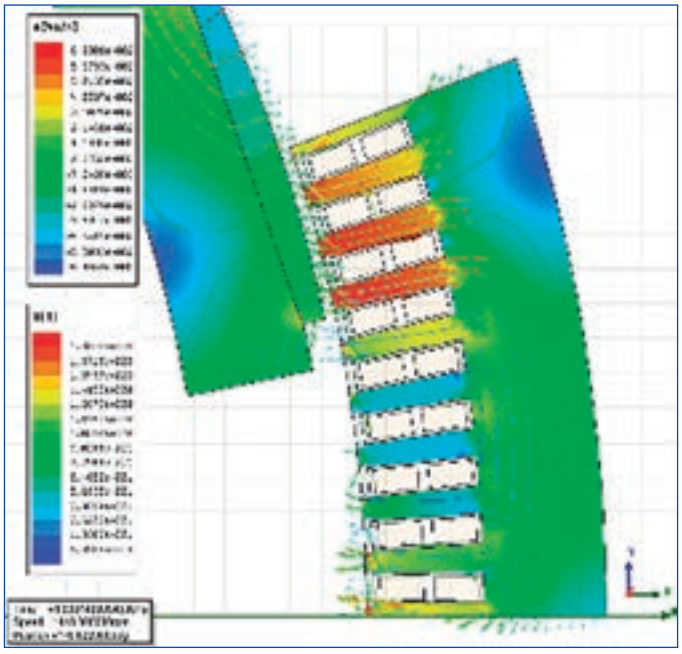


Figure 2: Characterization of the Generator Model

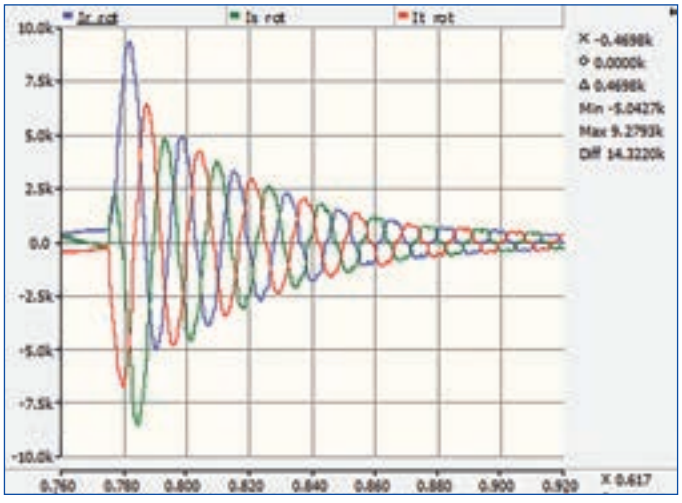


Figure 3: Modelization of Rotor Current during an FRT Event

Voltage control in wind farms is usually tuned for strong grids, making the control dynamics not suitable for weak grids. The voltage control is not able to keep the grid voltage within the voltage range of the generation systems, as a weak grid presents high ratios of dV/dQ.

The company's Crowbarless solution is able to keep the control of the wind turbine during the voltage transients in the grid, achieving the controllability required in order to operate in weak grids.

Despite the above-mentioned points and regarding the grid compliance, it has to be taken into account that both the power converter and the generator generate current harmonic content

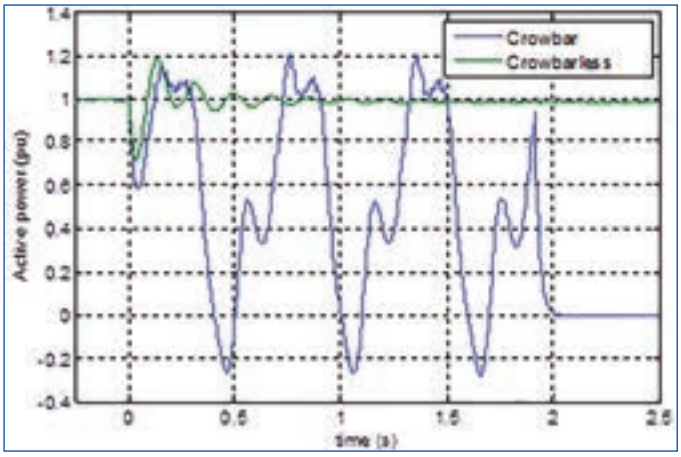


Figure 4: Active Power during an SCR change from 5 to 2, with Crowbar and Crowbarless systems

that is supplied to the grid. The current harmonic content generated by the converter depends on the grid frequency and switching frequency, so this is commonly filtered by standard and well-known filter topologies. However, the current harmonic content generated by the generator is slip dependent, since it is produced because of design limitations in the core and air gap. In this case, active filter topologies are usually needed in order to attenuate them.

As for the efficiency, DFIG converters show a very good performance in high and stable wind locations (>8m/s). Considering that they manage approximately 30-40% of the whole power of the wind turbine, the impact of the converter in the efficiency is minimal and the typical values are around 99% at full load. Instead, at partial loads, the efficiency of the wind turbine is reduced, but the impact of the converter in it is low.

To solve all these issues, we include in our converters both hardware and software solutions to mitigate the harmonic content of the system, pass through FRT events and work in weak grids. Our expertise in wind energy application and the customisation of our Ingecon® wind power conversion systems, achieve the fulfilment of the most restrictive requirements as well as the minimisation of the wind turbine LCoE for global solutions. Meaning, the knowledge of the whole system along with a modular design including several kit options always allows offering the most optimal solution in terms of cost and performance.

FC Topology Converters

The Full Converter topology, unlike DFIG turbines, completely decouples the generator from the grid. In this sense, the generator can work at any rotational speed. Besides, changes in grid voltage do not affect the dynamics of the generator. This kind of wind turbine also provides complete control over active and reactive power exchanged with the grid.

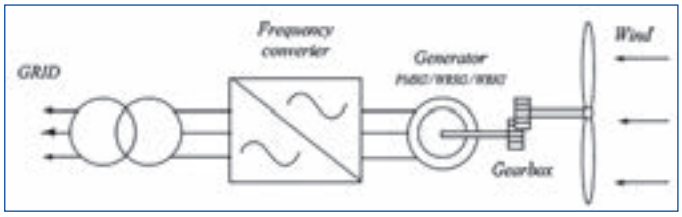


Figure 5: FC and Gearbox Diagram

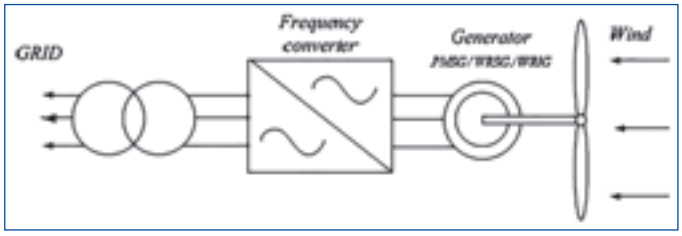


Figure 6: FC Diagram

- The converters have the generator rated power.
- Possibility to control the voltage and reactive power in the grid without affecting the dynamics in the generator (as long as there is no grid fault).

As mentioned for DFIG applications, FRT events, weak grid operation, grid harmonic compliance and efficiency are also topics with a high impact on the FC wind turbine's overall performance. In this sense, FC applications do not suffer such big currents during FRT events, as the generator is completely decoupled from the grid, and as a result, the fulfilment of the FRT event is not as complicated as in DFIG turbines. Nonetheless, the recovery of the dip and the management of the surplus energy stored in the DC-Link has to be solved in a smart way in order to be able to continue in operation and be connected to the grid.

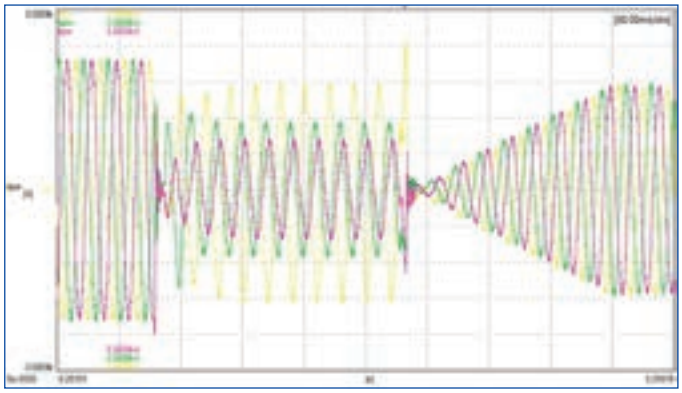


Figure 7: Grid Voltage 2ph 20% dip R, S, T

Operation in weak grids is also a challenge for FC topologies. The resonance frequency of the filter can vary along with the SCR value, and thus, control logics could be affected. To avoid any possible instability, advanced active damping strategies must be used.

As for grid compliance, the usage of different modulation strategies, different switching frequencies and different filter topologies ease the fulfilment of the more and more strict grid codes. In this sense, Ingeteam offers different modulation strategies along with different kit options that lead to the fulfilment of the strictest grid codes, offering always the best possible LCoE.

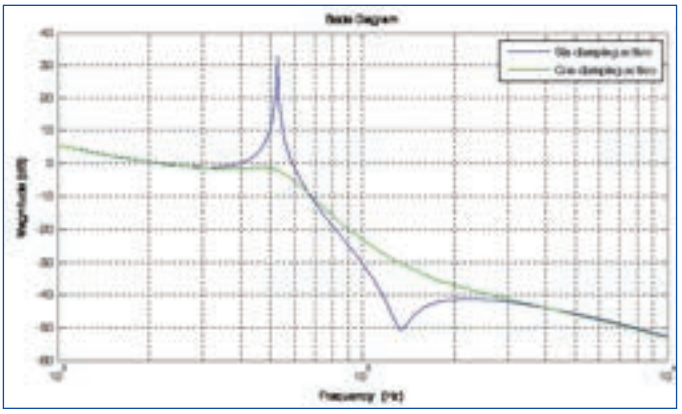


Figure 8: Active Damping

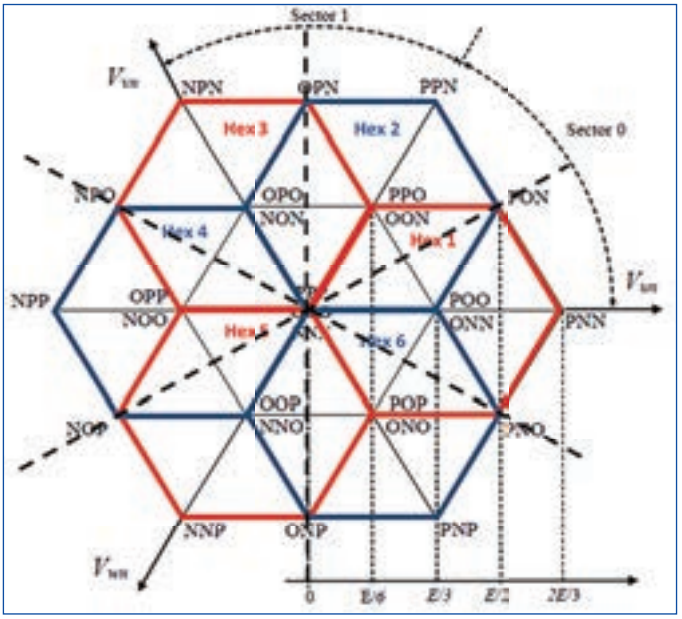


Figure 9: Modulation

In Full Converter applications different configurations may be considered depending on efficiency vs. initial cost trade-offs. The following variables are the main drivers when it comes to the final solution selection.

- Converter topology:
  - 2 level topology.
  - 3 level topology NPC (Neutral point clamped).
- Voltage level:
  - Low voltage.
  - Medium voltage.

- Generator type:
  - Induction generators.
  - Permanent Magnet generators (PMG) in medium speed or direct drive.
- Transformer location:
  - Up in the nacelle.
  - Down in the tower.

Comparing 3 level topologies with 2 level topologies, for the same AC voltage level, both current and Total Harmonic Distortion Voltage (THDv) are reduced, thus optimizing the filter (reduced costs and losses) and minimizing the losses in the power stack. Moreover, if the AC voltage is increased, i.e. up to 3100V (medium voltage), the efficiency of the whole solution is increased accordingly and the wind turbine manufacturer will have more flexibility when it comes to locating both the converter and transformer.

On the other side, the number of semiconductors is higher in 3 level NPC topologies. Also, medium voltage semiconductors are more expensive, but for the same power, the number of semiconductors could also be reduced.

As for generators, induction generators are widely used in the wind sector. They offer a very good trade-off between performance, size, reliability and cost. These are the main reasons that have led this technology to become popular, in the wind sector.

Nonetheless, it is well known that PMG generators offer a better performance in terms of efficiency, speed range and torque density, and not only at full load but also at partial loads. Moreover, PMG direct-drive generators do not require a gearbox, thus reducing the initial cost and maintenance. On the contrary, however, the temperature of the converter semiconductors is increased for continuous low frequencies. Another drawback of a permanent magnet generator is the cost of the magnets that suffer unpredictable cost variations and have a big impact on the final cost of the generator.

The transformer location is a very important topic when it comes to drivetrain topology selection. Depending on the space constraints, structural stresses, efficiency and maintenance, different solutions are available.

Evaluation

Deciding which topology to use is not straightforward. A chart based on the evaluation of the most relevant characteristics of each option could help in the evaluation process and choice.

The different options are benchmarked using a 0 to 5 score system, where 5 is given to the best option. The remaining option is then rated proportionally according to the figures provided in the table. That is, the further away from the centre in a curve, the better the option. Therefore, if one of the proposed arrangements surrounds its counterpart in the chart, it would mean that it is superior.

KEY FEATURE	DESCRIPTION
Output Voltage	Weighs the possibility to use standard voltage values (use of standard transformers, cabling, breakers, …)
Price	Weighs the price of the solution
Volume	Weighs the volume of the solution
Weight	Weighs the weight of the solution
Power Density	Weighs the power density measured in MW/m3 of the solution
Grid Side Filter	Weighs the design – volume – efficiency of the grid side filter to fulfil the specifications (harmonics)
Efficiency	Weighs the efficiency of the solution
Grid Code compliance LVRT behaviour	Weighs the feasibility, compliance and capacity to adapt to further requirements related to grid codes.
Maintenance	Weighs the maintenance level that is expected for the proposed solution
Design Flexibility	Weighs the design flexibility in terms of converter location inside the wind turbine.

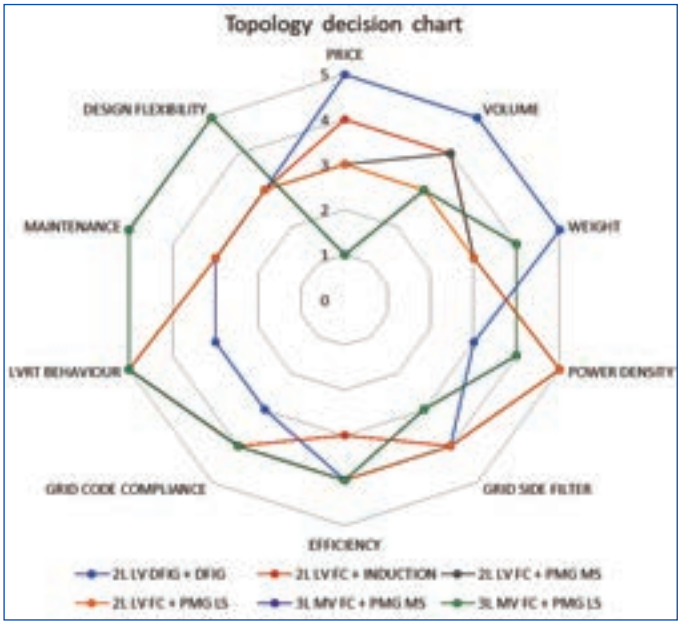
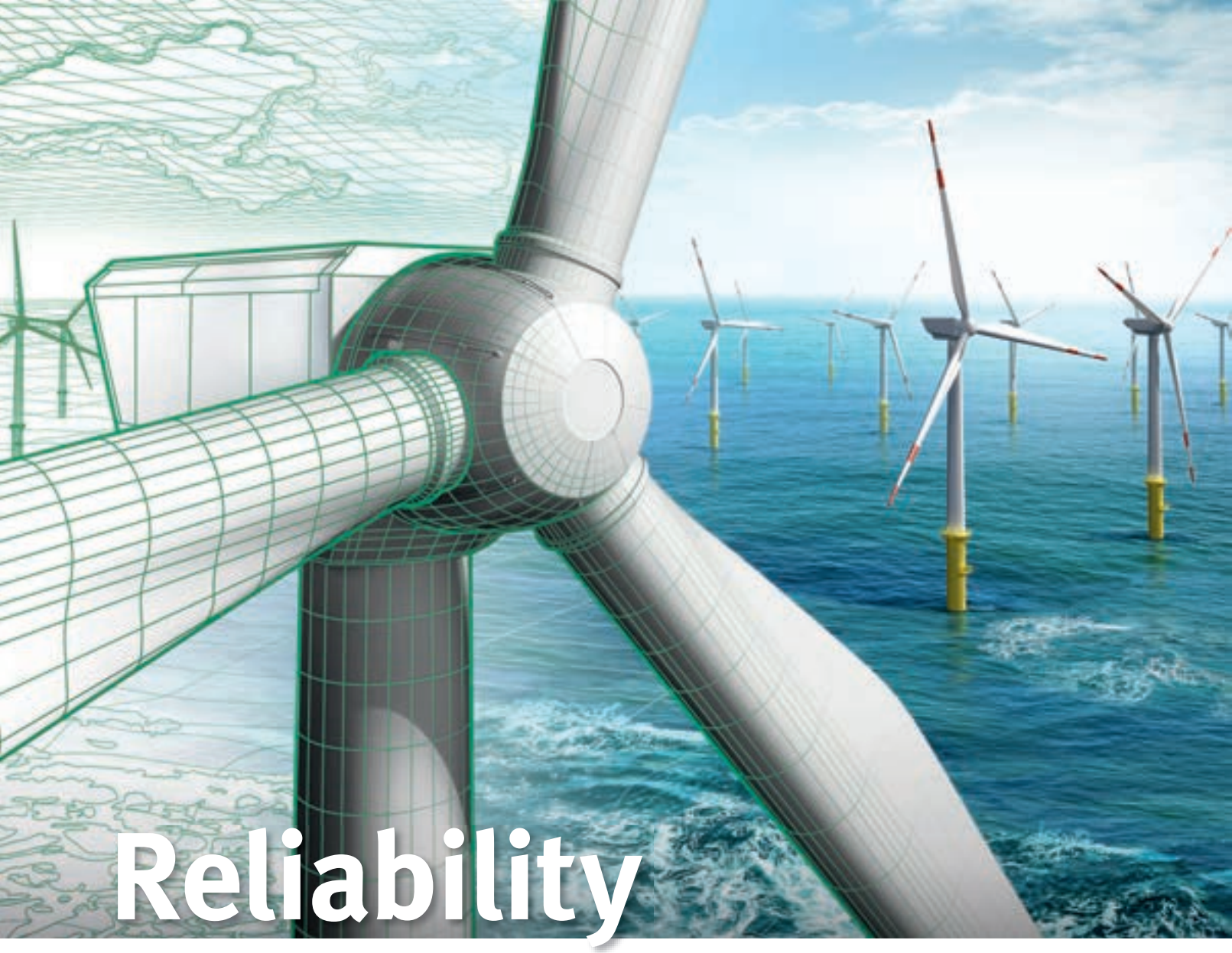


Figure 10: Topology Decision Chart



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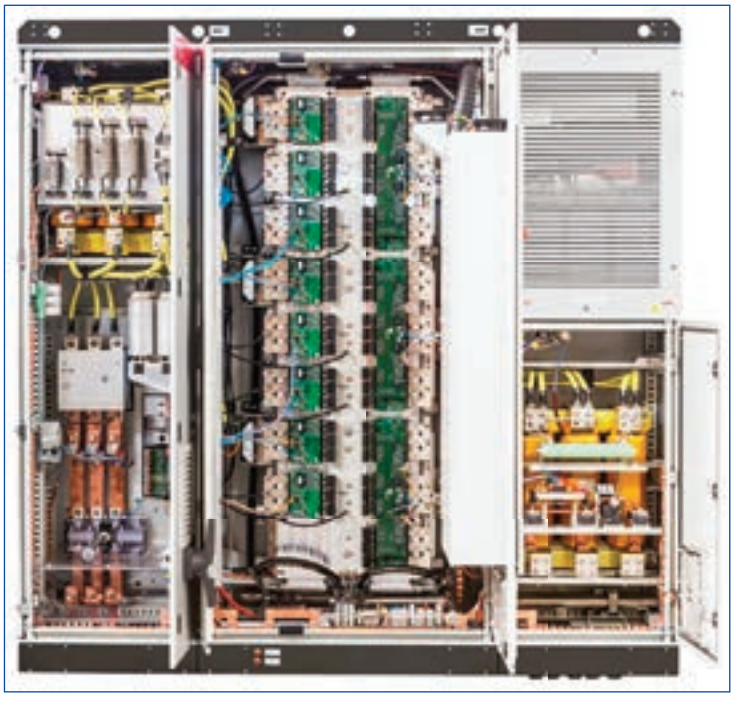

Figure 11: DFIG Power Converter

The final decision is open and dependant of the final system and location. This is the main reason why top OEMs have chosen different solutions in terms of electrical topology. The main decision drivers are not constrained just to one topic and the whole picture needs to be considered.

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LVRT and Grid Management

Dr. Sanjiv Kawishwar, Senior Vice President
Technology & System Certification, ReGen Powertech Private Limited

Even short voltage sags can cause a Wind Turbine Generator (WTG) to shutdown for hours. Without a low-voltage-ride-through (LVRT), a cascading effect can cause loss of generation that may exceed the primary operating reserves of the grid. This issue is fundamental to the objective of load balancing, and cannot be addressed simply by better forecasting.

LVRT requirement takes the form of mandated continuous connectivity with respect to a voltage-time characteristic. In addition, grid codes usually require reactive power feed-in to stabilize grid voltage. LVRT thus constitutes a voltage control strategy on the generator-side to minimize the impact of grid faults.

LVRT performance constitutes the main part of fault-ride-through (FRT) performance, that captures all the requirements of a generator protection system.

Connectivity Issues for WTGs

Causes of Voltage Sag

Voltage sags are fundamentally caused by a temporary decline in wind speed, but may be on the grid side affecting the WTG in a cascading effect. Such grid faults include heavy current on lines, which affects voltage levels in the vicinity.

Transient operation of the WTG, such as system switching operations, can draw large currents (short circuit) causing dip in voltage. Such conditions result in severe transient dynamics for voltage sags. Generator fault occurs when a short circuit causes components to be disconnected before damage.

Grid Aspects of Voltage Sag

Voltage sags relevant to the LVRT requirement are measured at the point of common coupling (PCC), i.e. the grid point where the wind power installation is connected to the grid users.

Short-circuit ratio (SCR) is defined as the ratio of short-circuit power at the PCC to maximum demand. Higher the ratio, lower the voltage disturbance resulting from current disturbances, thus muting the cascading effect.

Cascading events that result in islanding of generators can also lead to a sharp voltage dip. However, such a dip is of smaller magnitude (0.1-0.2 pu) compared to the large sags (near 1.0 pu) caused by a short-circuit fault.

Harmonic current at the PCC depends on the configuration of the wind farm. Therefore, specified LVRT performance of a WTG can only be an approximation to the actual online performance.

Benefits of LVRT Strategy

RE sources usually have lower short-circuit currents, which means that a connectivity period is not necessary for fault detection. The continuous connectivity period mandated for LVRT however provides an opportunity to implement condition monitoring algorithms that can diagnose WTG faults during the voltage dips.

Reactive power can only be transmitted locally, and thus support is desirable for good grid performance. Reactive power support provided by a WTG may be critical in determining its online voltage recovery performance.

LVRT Requirements according to CEA Notification

While grid connectivity for RE sources were discussed in draft IWGC 2009 and draft IEGC 2010 regulations, LVRT and power quality requirements were first mandated in the CEA Amendment (2013) Regulations on Technical Connectivity to the Grid (Notification 12/X/STD(CONN)/GM/CEA on 15.10.13).

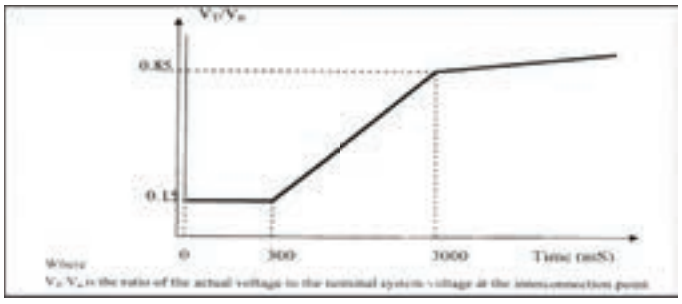
Frequency control is mandated, it is also important for load balancing and must be achieved with +-5% limit for voltage. Automatic frequency control and active power set-point control are implemented together as load frequency control (LFC) that helps to control voltage.

LVRT functioning requires a control scheme for:

a. Reduction of active power injection in proportion to the retained voltage

b. Maximization of reactive power support to the grid for the duration of the voltage dip or for 300ms, whichever is lower

c. Requirement of continuous connectivity to the grid in the operating region above the ramp line in the voltage-time characteristic below



Mandated Voltage-Time Characteristic for Connectivity (from 2013 CEA Notification 12/X/STD(CONN)/GM/CEA, p. 9)

The reduction of active power is in order to free up capacity for reactive power support. Generators usually implement an outer control loop to change active power set-point, which enables the LVRT control mode. The regulation requires that the set-point control be made available to the appropriate Load Despatch Centre (LDC).

Grid Codes

The stability issue is the greatest at voltage levels where the highest power capacities are connected to single connection points. The draft IEGC 2010 required LVRT for substations at 33kV and above, while the actual CEA 2013 Amendment specifies 66kV and above.

As the share of RE sources in the grid rises, a protection code at lower voltage grids helps the smooth functioning of the grid. The German Grid Code mandates the LVRT requirement for low-voltage grids also (VDE-AR-N 4105).

Stability of the Inter-State Transmission System (ISTS) voltage is a key issue identified in IEGC 2010 (Sec 4.6.1) and forms the ultimate objective for reactive power feed-in. The State Transmission Utlity (STU), or the User directly connected to ISTS, is responsible for reactive power feed-in to stabilize ISTS voltage. The Regional Power Committee (RPC) in consultation with the Regional LDC can occasionally require additional reactive compensation.

Standards for LVRT Testing

The main technical standards for LVRT testing are:

a. IEC 61400:21-2008 Ed2: Wind turbine generator systems- Part 21: Measurement and assessment of power quality characteristics of grid connected wind turbines

b. FGW-TG3: Determination of the electrical characteristics of power generating units and systems in medium-, high- and extra-high voltage grids

Simulation results may be useful in complementing measurements. IEC 61400:27-1 provides a standard for electrical simulation models to be used for different turbine types. The equivalent FGW standard is FGW-TG4.

DNV-GL standard DNVGL-ST-0125 (2016) follows FGW-TG3/ TG4 for assessments, and harmonizes with the grid code certification scheme DNVGL-SE-0124 which can optionally assess test results for global grid compliance.

LVRT Certification Process

Type Certification Scheme GL 2010 makes LVRT testing optional, while the IEC 61400:22 scheme makes the whole power quality testing optional.

WTGs certified under an older scheme (GL 1999, GL 2003, IEC-WT-01, TAPS 2000) need to be upgraded to GL 2010/ IEC 61400:22/ IECRE OD-501/ DNVGL-SE-0074/ DNVGL-SE-0441 to achieve CEA compliance.

A statement to CEA notification compliance is included in Prototype Certificate (SOC- TT) as well as final evaluation report, whereas LVRT technical compliance details are included in electrical characteristics report.

Either the Type Certificate of wind turbines should include CEA notification compliance under Prototype Testing Certificate (SoC), or in a separate Conformity Statement (CoC).

The Type Certification Body must be accredited for the CEA Notification 12/X/STD(CONN)/GM/CEA dated 15.10.2013.

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Development of Wind–Solar Hybrids in India

National Wind–Solar Hybrid Policy

India has declared the trajectory of bidding 60 GW capacity of solar energy and 20 GW capacity of wind energy by March 2020, leaving two years' time for execution of projects. The draft National Wind–Solar Hybrid Policy brought out in 2016 (https://mnre.gov.in/file-manager/UserFiles/Draft-Wind-Solar-Hybrid-Policy.pdf) was finalized after detailed consultation with the stakeholders and the Ministry of New and Renewable Energy has issued National Wind–Solar Hybrid Policy vide letter No. 238/78/2017-Wind dated May 14, 2018. The objective of the policy is to provide a framework for promotion of large grid connected wind–solar PV hybrid system for efficient utilization of transmission, infrastructure and land. The policy aims at encouraging new technologies, methods and way-outs involving combined operation of wind and solar PV projects.

The Policy seeks to promote new hybrid projects as well as hybridisation of existing wind/solar projects. The existing wind/solar projects can be hybridised with higher transmission capacity than the sanctioned one, subject to availability of margin in the existing transmission capacity. A wind–solar project will be considered a hybrid project if the rated power capacity of one resource is at least 25 percent of the rated power capacity of other resource. The power procured from the hybrid project may be used for fulfilment of solar RPO and non-solar RPO.

No additional connectivity or transmission capacity charges will be levied by the respective transmission entity for the hybridization at existing wind or solar projects.

The National Wind–Solar Hybrid Policy can be viewed from the link below.

https://mnre.gov.in/sites/default/files/webform/notices/National-Wind-Solar-Hybrid-Policy.pdf

State Wind–Solar Hybrid Policies

Gujarat Wind–Solar Hybrid Policy

Government of Gujarat has come up with Wind–Solar Hybrid Policy 2018. This policy aims to scale up installation of Wind & Solar Hybrid Power Projects in order to minimize the variability apart from optimally utilizing the required infrastructure including land and transmission system. The link for the policy is given below.

https://guj-epd.gujarat.gov.in/uploads/Gujarat_Wind-Solar_Hybrid_Power_Policy-2018.pdf

Andhra Pradesh Wind–Solar Hybrid Policy

The government of Andhra Pradesh has recently announced a new wind–solar hybrid policy as the state targets to achieve 18000 MW of renewable capacity by the year 2021-2022. The policy can be viewed from the link below.

http://nredcap.in/PDFs/Pages/AP_Wind_Solar_Hybrid_Power_Policy_2018.pdf

Summary of Andhra Pradesh Wind–Solar Hybrid Policy

Period of Enforcement: This policy shall remain applicable for a period of five (5) years from the date of issuance and/or shall remain in force till such time a new policy is issued or this policy is withdrawn, modified or superseded by the Government. The Wind–Solar Hybrid Projects that are commissioned during the operative period shall be eligible for the incentives declared under this policy, for a period of 10 years from the date of commissioning.

Wind–Solar Hybrid System: There can be different approaches towards integrating wind and solar depending upon the size of each of the source integrated and the technology type.

In the locations where the wind power density is quite good, the size of the solar PVs capacity to be added as the solar-hybrid component could be relatively smaller. On the other hand, in case of the sites where the wind power density is relatively lower or moderate, the component of the solar PV capacity could be relatively on a higher side.

Share of Resource: Recognized as Hybrid Plant if the rated power capacity of one resource is at least 25% of the rated power capacity of other resource. **CUF: 40%**

Hybridization: Hybridization is allowed for new wind–solar hybrid plants and existing Wind/Solar PV Plants.

1. The hybrid power generated from the wind–solar hybrid project may be used for (a) captive purpose; (b) sale to third party through open access; (c) sale to the distribution company(ies) either at project specific tariff determined by the APERC or at tariff discovered through transparent bidding process; or (d) sale to the distribution company(ies) at APPC under REC mechanism and avail RECs.
2. The power procured from the hybrid project may be used for fulfillment of solar RPO and non-solar RPO in the proportion of rated capacity of solar and wind power in the hybrid plant respectively.

Energy Banking & Drawal: Banking of 100% of energy shall be permitted during all 12 months of the year, based on the feasibility and prior approval of APTRANSCO/APDISCOMs. Banking charges shall be adjusted in kind @ 5% of the energy delivered at the point of drawal. The banking year shall be from April to March. Energy settlement shall be done on monthly basis. The unutilized banked energy shall be considered as

deemed purchase by Discoms at 75% of the Average Pooled Power Purchase Cost as determined by the APERC for the applicable year.

Energy Storage: Any Energy storage technologies like Mechanical, Chemical, Compressed Air, Hydrogen, Pumped Storage, etc. may be added to the hybrid project.

Incentives: The projects which are developed by the manufacturers are given preference for sale of power to distribution company(ies) either at project specific tariff determined by the APERC (or) a tariff discovered through transparent bidding process (or) at APPC under REC mechanism and avail RECs.

Other Incentives

1. Transmission and Distribution charges shall be exempted up to 50%.
2. 50% of applicable Electricity duty shall be exempted for captive consumption, sale to DISCOMs and third party sale provided the source of power is from wind–solar hybrid power projects set up within the State.
3. 50% of the Cross Subsidy Surcharge shall be paid for third party sale provided the source of power is from Wind–Solar Hybrid Power Projects setup within the State.
4. Wind–solar hybrid power projects will be exempted from paying the supervision charges.
5. Deemed Public Private Partnership (PPP) status shall be provided for projects coming up as wind–solar hybrid power projects as per this policy.
6. Deemed Non-Agricultural (NA) status for the land where wind–solar hybrid power projects will be accorded, on payment of applicable statutory fees.
7. Wind–solar hybrid power projects will be exempted from obtaining any NOC/consent for establishment under pollution control laws from AP Pollution Control Board.
8. All Wind–Solar hybrid power projects shall be treated as "MUST RUN" power plants and shall not be subjected to 'Merit Order Despatch (MOD) principles.

Some Wind–Solar Hybrid Projects

- In January 2018, Solar Energy Corporation of India (SECI) had invited expressions of interest (EoIs) from engineering, procurement, and construction (EPC) contractors to develop a 160 MW of large-scale solar wind hybrid project with an energy storage system in the Ramagiri district of Andhra Pradesh. The scope of work includes the design, engineering, procurement, supply, construction, installation, testing and commissioning of the 160 MW grid-connected hybrid power project with an energy storage system and the associated transmission facility.

  The above bid submission has resulted in participation of 3 JVs.

  1. LNT-Gamesa – 160 MW
  2. Suzlon-Sterling – 160 MW
  3. Senvion, Alfanar & Rays Power – 160 MW

- The National Thermal Power Corporation (NTPC) has amended the tender for the development of wind–solar hybrid power project at NTPC Kudgi, Karnataka. The tender was previously issued in October 2018. Under the amendment, the minimum wind capacity is now 44 MW (± 10 percent) reduced from the earlier 60 MW, while nominal solar capacity is 130 MW. A bidder can offer the solar capacity higher or lower than the nominal capacity of 130 MW after freezing the wind turbine generator micro-siting to achieve the minimum cost for the whole wind and solar hybrid project.

- MNRE has announced Scheme for setting up of 2500 MW ISTS connected Wind Solar Hybrid Projects where the price will be discovered through transparent process of bidding through SECI. The link is given below.

  https://mnre.gov.in/sites/default/files/schemes/Hybrid%20Scheme-ilovepdf-compressed.pdf

  Solar Energy Corporation of India (SECI) had issued a Request for Selection (RfS) document for 2.5GW of hybrid wind and solar projects to be connected to the Interstate Transmission System (ISTS) in June 2018. The minimum capacity for a single bidder is 200MW, with a maximum of 500MW. The minimum project size at a single location is 50MW. 25-year power purchase agreements (PPA) will be signed with SECI. An upper ceiling tariff has been fixed at INR2.93/kWh (US$0.043).

  SECI amended this RfS for 2,500 MW of ISTS-connected wind–solar hybrid power projects (tranche-I) in November 2018 and reduced the project capacity to 1,200 MW from the earlier 2,500 MW. The tariff for this bid on 5th December 2018 was @ Rs. 2.67 by SBE Renewables for 450MW and @ Rs. 2.69 by Mahoba Solar (Adani) 390MW.

  The Maharashtra State Electricity Distribution Company Limited (MSEDCL) has issued a one of a kind wind–solar hybrid tender which gives the developers freedom in project development. The state distribution company has set ₹ 2.75/kWh as the upper tariff ceiling for this tender, calling interested parties to submit their bids and the capacity they want to develop.

- At present, only Hero Future Energies has a hybrid project with both solar and wind capacities to be set up in one location at Kavithal village in Raichur District in Karnataka state by adding 28.8MW solar PV site to an existing 50MW wind farm. This is the India's first large-scale wind–solar hybrid project.

- Some other companies are also in process of entering in to the area of wind–solar hybrid.

Compiled by: **IWTMA Team**

Solar Wind, Hybrid Renewable Energy Systems

Venkat Kumar Tangirala, President - India and South East Asia
WindStream Energy Technologies India Private Limited, www.windstream-inc.com

Introduction

Energy drives global economic activity. The living standards of the people across the world is on the rise and with ever expanding population, the total demand for energy is expected to increase by 21% by 2030, according to estimates from IEA, 2015. While catering to the energy demands of the people is a priority, Governments across the globe have an obligation to ensure that the climate is protected for future generations. Hence, there is a lot of emphasis on sustainable renewable energy across the world.

According to a report from World Economic Forum, the energy sector influences the vibrancy and sustainability of the entire economy – from job creation to resource efficiency and the environment. Major shifts in the sector can have a strong ripple effect throughout the economy as evidenced in Japan following the 2011 earthquake, or by the recent volatility in oil prices. Making the energy supply more cost effective, reliable, secure and environmentally sustainable contributes to the long-term resilience of economic development.

Supported by technology advancements, ever increasing energy demands, steep reduction of manufacturing costs and enabling policies, the deployment of renewable energy solutions has seen a remarkable growth in the past decades. Renewable energy solutions not only improve the energy security but also assist communities in energy accessibility, job creation and fewer adverse climate change impact. According to a report by IEA, the renewable energy sector is expected to provide employment to over 24 million people by 2030.

The peak power demand in India is not more than 170 GW and our installed capacity is 349.288GW as on 31st December 2018 (CEA). Despite this, we have power shortages and blackouts. This is due to insufficient fuel availability and excessive costs.

Renewable Energy

Renewable energy is free source of energy, clean, affordable, and effectively infinite. It produces no emissions and results in cleaner air. The renewable energy cannot be depleted like fossil fuels. Fossil fuels are limited, and will be unavailable but the same scenario will not happen with renewable energy sources because Sun will continue to shine, wind will continue to blow. Renewable energy generation systems like solar, wind and bio are the promising and the most important renewable energy technologies. The wind power industry is one of the fastest expanding industries because of rapid growth of installed capacity.

According to a report by Bloomberg, the amount of energy produced using fossil fuels will see a sharp decline in the coming few years while energy produced through clean energy sources will increase substantially. The most preferred sources would be solar and wind.

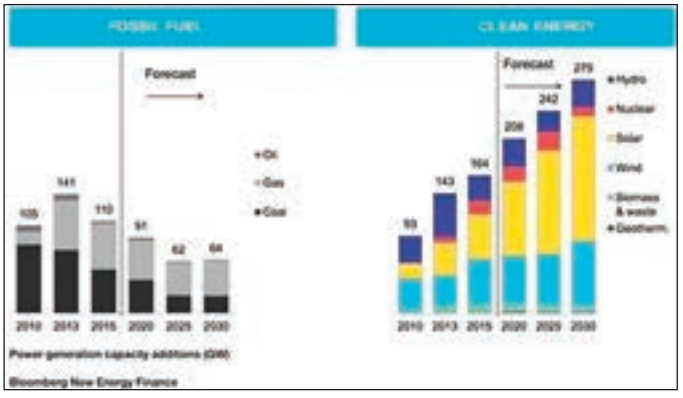

Figure 1: Forecast of Fossil Fuels and Clean Energy

As on 31st December 2018, total renewable energy is 74081.66MW out of which small hydro is 4517.45MW, Wind 35138.15MW, solar 25212.26MW and biomass is 9213.80MW. Big hydro are another 45399.22MW.

India has been steadily investing in its renewable energy sector and is expecting to increase its overall renewable energy capacity from 74 GW in 2018 to about 175 GW in 2022.

Solar Energy

Solar power is derived from Sun's radiation. It is interesting to note that the energy that Sun provides to earth for an hour can meet the energy demands of the entire planet for a year. However, we are able to harness only 0.001 percent of that energy. Solar energy was not very popular due to inefficiencies in the systems and higher cost. However, due to higher energy

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demand, the technology has been improved considerably making it a very efficient source of clean energy.

In 2017, global cumulative solar PV capacity reached almost 398 GW and generated over 460 TWh, representing around 2% of global power output. India has made rapid progress from 2010 in Solar energy, increasing its capacity to 25.21 GW as of 31 December 2018.

Advantages of Solar Energy

Solar Energy has many advantages.

- It is a clean source of energy
- Abundance of the resource – according to estimates by Government of India, India can generate 10,000 GW of solar energy
- Sustainable
- Needs less infrastructure compared to traditional fossil fuel based power generation units
- Easy and quick Installation
- Very less carbon footprint for manufacturing of the photovoltaic cells
- No noise during operations, hence can be installed in residential neighbourhoods
- Power can be generated at the place of consumption
- Low cost of operations
- Technology advancements have driven down the cost of production
- Affordable. Government Policy on Solar Energy has improved the affordability further
- Suitability – according to Government of India estimates, most parts of the country are suitable for installation of solar energy units, including space needed.

While solar energy has many advantages over traditional energy generation options, it has its share of drawbacks.

- Available only for 20% to 30% (4 to 6 hrs) in a day
- For mass production, it requires large surface areas
- Power storage is expensive as it requires more batteries for storage during non-sunny days. Also, solar batteries are relatively expensive.
- Seasonality of the source. Power generation reduces dramatically during times of cloud cover.
- Not suitable for power generation across all regions
- Efficiency of solar panels – at present the panels can only convert about 22% of the available sunlight to electricity. Efficiency of the panels can be improved further.

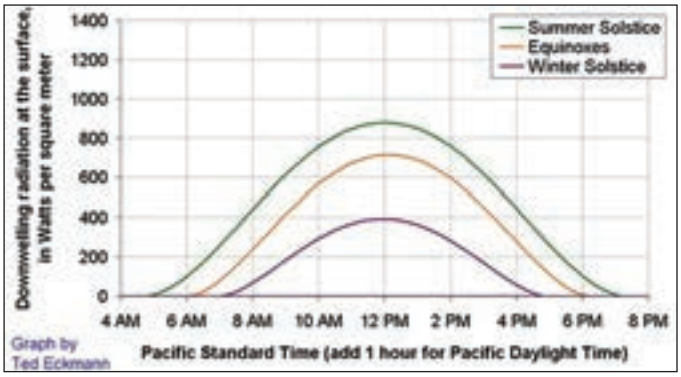

Figure 2: Solar Radiation during Various Times of the Day

Wind Energy

Wind is technically a form of solar energy. Winds are caused by the heating of the atmosphere by the sun, the rotation of the Earth, and the Earth's surface irregularities. Wind energy is derived from the winds that blow across lands and seas. Wind turbines convert the kinetic energy in the wind into electricity. For as long as the sun shines and the wind blows, the energy produced can be harnessed to send power across the grid

Wind power, as an alternative to fossil fuels, is abundant, renewable, clean, widely distributed, consumes no water and uses little land. Wind farms are established where there is abundance of wind to generate power and is supplied to the grid. Variance in wind speed makes the wind energy unreliable; hence it is always used in conjunction with other energy sources. Offshore wind farms provide more reliable wind energy however they are very expensive to build.

Wind energy contributes about 23% of global renewal energy production and about 4% of the global energy production. While the current wind power capacity is about 35 GW, India aspires to grow that to about 60 GWs by 2022.

Advantages of Wind Power

- It is a clean source of energy. According to the Wind Vision Report, wind has the potential to reduce cumulative greenhouse gas emissions by 14%, saving $400 billion in avoided global damage by 2050
- Sustainable
- Larger capacity in lesser space
- Availability of Modern Technologies
- Can be built on existing farms
- Does not consume water like the conventional electricity sources
- Negligible carbon foot print in manufacturing of the equipment

- Job Creation - In 2016, the wind energy employed more than 101,000 workers (approximately 30% women, 11% veterans, and 25% minorities), according to the 2017 U.S. Energy and Employment Report. All over the world the job creation from wind energy installations is very high.

Figure 3: MW Scale Installations

While wind energy has many advantages over traditional energy generation options, it has its share of limitations.

- Seasonality – Wind energy across geographies is seasonal, hence the reliability of wind energy is low.
- Cost of power – The cost of power generated by wind mills is directly dependent on the wind speed at the site. At lower wind speeds, the cost of wind power is more as compared to higher wind speed. Now with the advancement in technology and more hub height, the wind power tariffs are at par or even lower than the traditional power.
- High installation costs – While the wind energy systems are very expensive to manufacture and install, most of the locations suited for wind energy are in remote places escalating the cost of installation.
- Noise Pollution – Wind turbines create noise hence not very suitable for installation in residential areas.
- Visual Impact to Landscape – Typically wind turbines are setup at a height of 50-120 mts above the ground and hence impact the view of the landscape.
- Suitability – Wind energy is not suitable for every type of geography. In India, 9 states are very well suited for sustained wind energy.
- Higher transmission costs – Since wind mills/farms are established in remote areas, high costs are incurred to setup new transmission lines to connect to the grid. This may be compensated by the large farms at one site.

The Solution – Wind–Solar Hybrid

There is a way to combine the positives of both wind and solar power units to offset the drawbacks that they individually have and still be effective?

Hybrid Energy combines the forces of solar and wind to generate electricity. It is interesting to note that the natural resources required for wind and solar complement each other and hence a hybrid setup can generate more power reliably than a solar or wind energy plant individually. The figure below shows the solar irradiation and wind speeds in Chennai. When you notice the graph closely, you will notice that when the wind energy decreases, the solar irradiation picks up and vice versa, thus ensures continuous production of energy across all seasons and all times of the day.

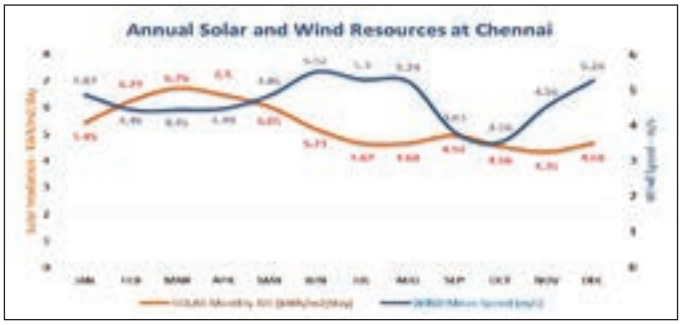

Figure 4: Annual Solar and Wind Resources at Chennai

A hybrid system will help improve the efficiency of the batteries, as the charging and discharge cycles are more uniform, thus reducing the cost of the batteries and improving its life. As a hybrid system depends both of solar and wind, the area required for deployment is also greatly reduced. Below are some of the major advantages of the hybrid system.

Advantages of a Hybrid System

- More energy density (energy per sq. meter) can be obtained
- Best suitable for distributed energy
- Based on the location and the availability of wind and solar sources at the location, the design of the system can be altered to gain the best from the available sources
- Battery will work efficiently as continues power generation can be obtained therefore, smooth charging and discharging can be seen
- Low cost of operations
- Increased efficiency – Since the energy density is more, the system can operate at a much higher efficiency that traditional wind and solar systems
- Because of increased efficiency, hybrid energy systems can be deployed at places of consumption, thus reducing the costs of transmission and transmission losses
- Lower installation costs compared to solar and wind energy only installation

- Cost of power is much lesser than power from the grid over its life time
- Due to continuous power generation, there is even an option to supply power to the grid, at times of low usage thus making it more efficient and economical
- Effective space utilisation – Hybrid systems when designed well can occupy much less space than traditional wind only or solar only installation. Thus, more energy can be produced from the same space.

Design of the hybrid system is very important to ensure that the benefits are fully realised. Windstream Technologies Inc has designed a very effective Hybrid Energy solution that is very reliable, modular, scalable and efficient with a very high ROI.

The SolarMill® that WindStream Technologies' manufactures is based on a modular, scalable, distributed renewable energy system designed and optimized for on and off grid installations. At its core is a highly efficient wind energy device, utilizing three (3) low-profile vertical axis wind turbines (VAWT) mounted on a single base. The units can be interconnected to increase energy production capability in low speed and turbulent wind environments commonly found at lower elevations.

To provide more consistent energy generation than a "wind only" or "solar only" system, we incorporates Photo Voltaic (P.V.) technology within a compact footprint, creating the greatest energy generation density. The hybrid concept of this is unique, seamlessly utilizing wind and solar energy generation in one unit. This allows the product to be an effective solution in markets where the natural resources available for wind or solar energy alone do not justify investment into any small wind product. It is simple, efficient and cost-effective way to utilize available wind and solar resources in "India".

Figure 5: A 10 kW Hybrid Installation @ Industrial area Shammerpet, Hyderabad

Performance of a Well-Designed Hybrid System

- Roof top wind and solar hybrid energy system.
- 24-hour power production capability
- Higher power density per square foot
- Scalable power generation.
- Mechanical braking at high-speed winds beyond 18.5 m/s.
- Appropriate for on or off grid applications
- Offsets peak energy pricing for grid tied systems
- Minimizes backup battery storage requirements
- Online tool for power generation monitoring
- Power generation starting at 2 m/s wind speed
- Easy to mount on any rooftop; no complicated masts, guy wires, or towers
- Simple ballasted installation that avoids roof penetration.
- Visually engaging design complementing building facade
- Environment-friendly, silent operation
- Cost effective

Comparison of the Benefits of a Hybrid System with Solar and Wind only Installations

	Solar	Wind	Hybrid*
Production	• **Daytime only** • Production varies on the irradiation availability • Dependence on weather conditions • A typical 10KW system generates about **14,850 KW /Year**	• **Production varies** on the wind availability • Higher cut in speed (avg. of 3m/sec) • Production is intermittent and is seasonal	• **Produces day and night** (24x7x365) • Takes advantage of the **complimentary Solar and Wind sources** • **Reduces the variability** in renewable energy production • **Low cut in speed** of 2m/sec • A typical 10KW system generates about **16,000 KW/Year**

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Power Market goes Green

IEX is integrating Solar, Wind and Bio-Mass Generators on the exchange platform

So far the conventional power generators have been leveraging exchange markets, but now, it makes viable proposition to sell renewable power in the day-ahead market on the Exchange. Already, a few renewable generators have been selling on exchange platform at attractive prices compared to competitively bid tariffs.

IEX STATISTICS*

- 6,300+ Participants
- Participants located across 29 States & 5 UTs
- 50+ Discoms
- 4000+Open Access Consumers
- 500+Private Generators
- 148 MU Daily Average Cleared Volume

VALUE PROPOSITION

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- 4 hour Gate closure (Intra-Day)
- Diverse Participation

From Apr-Dec'18, 23 Solar generators with size varying from 3-100 MW sold 63 MU in day-ahead market

PRODUCT PORTFOLIO

- Electricity Market
  - Day-Ahead Market
  - Intraday and Day-Ahead Contingency
  - Term-Ahead Market
- Renewable Energy Certificates Solar & Non-Solar Certificates
- Energy Saving Certificates (ESCerts)

Solar | Wind | Bio-Mass | Thermal | Hydro

*Statistics for FY19 as on 31st December, 2018
MU=Million Units

IEX is approved and regulated by Central Electricity Regulatory Commission (CERC)

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	Solar	Wind	Hybrid*
Cost of installation	• **Moderate** installation costs • Based on the nature of installation, land costs are accrued • 10 KW on grid system costs about 8.5 Lakhs	• **Very high** installation costs because of the system as well as the land • Usually Wind Farms are established in remote areas, hence high costs are incurred to setup the transmission lines • 10 KW on grid system costs about 15 Lakhs	• **Moderate** installation costs • Land requirements are minimised due to increase in energy density • 10 KW on grid system costs about 9 Lakhs
Maintenance	• **Less** maintenance required • **Battery replacement costs are high** due to inefficient charge and discharge cycles	• **High** Maintenance & replacement costs due to wear & tear of the gears • **Battery replacement costs are high due** to bad charge and discharge cycles	• **Very Minimum**/no maintenance costs involved in the system • Lesser than Solar only solution, as the number of solar panels are less • No gears in the system • **Batter replacement costs are minimal** as the batter charge and discharge cycles are more uniform
Payback Period	• **6-8** Years	• **10-13** years	• **6-8** Years
Cost per KwH	• **$0.05 – 0.15**	• **$0.1 – 0.2**	• **$0.02 – 0.1**
Impact on Environment	• **Silent** Operation • Less impact on environment than traditional systems	• **High Noise** pollution • **Less impact on environment** than fossil fuel based solutions. • However, wind mills may **harm/ kill birds** • Some **trees have to be destroyed** to setup the transmission lines	• **Silent** Operation • **Lower impact than Solar only** solution, due to lesser use of solar panels
Energy Efficiency	• Energy Density of about **13W/Sqft**	• **Variable**	• Energy Density is **30W/Sqft**
Area required for a 10KW system	• **100 Sqmtrs**	• **100 Sqmtrs**	• **70 Sqmtrs**
Better Life	• **Low to Medium,** as the batteries charged only during the day time	• **Low to Medium,** as the batteries charge cycle is dependent of variable production	• **High,** as the batteries charge cycles are more uniform (charged 24x7x365)

Note: * Hybrid System as designed by WindStreamTechnologies

The SolarMill™ can generate power at wind speeds as low as 2m/sec to about 18m/sec and is so modular in design that it can be configured to generate the best energy density at any given site. Their hybrid system is scalable to setup a huge hybrid energy farm or setup on any kind of a roof top. WindStream Technologies has deployed their solution across many facilities in India and across the world.

Speciality Applications

Figure 6: 11kW Installation for Telecom Tower

Figure 7: Mobile Wind–Solar Mill

Figure 8: A 1.75 kW installation on Railway Crossing

Conclusion

With ever increasing energy demands and an urgent need to safeguard the world for the future generations, every country in the world is modifying their energy policy to decrease their reliance on fossil fuels and invest in renewable energy. Renewable energy sector will continue to witness huge demand and will generate millions of jobs around the world. Due to the seasonality and variability in wind energy generation, more and more people are now focusing on the solar energy. However, due to unavailability of the solar radiation at all times of the day, wind–solar hybrid solutions may be the norm of the future.

Snippets on Wind Power

Rajasthan Releases Terms and Conditions to Determine Tariff for Wind and Solar Energy

The Rajasthan Electricity Regulatory Commission (RERC) has issued second amendments to the terms and conditions for the determination of tariff for renewable energy sources (wind and solar) to come into force from the date of their notification in the Official Gazette. RERC will determine project specific tariff, on case to case basis.

FDI in Renewable Energy

India received Foreign Direct Investment worth $3,217 million in the renewable energy sector during the past over three years between April 2015 and June 2018 ($776 million in 2015-16, $783 million in 2016-17 and $1,204 million in 2017-18).

ET Energy World, December 28, 2018

Siemens Gamesa secures order for 126-MW wind projects in Maharashtra

Siemens Gamesa will provide the infrastructure to install and operate the facility, including supply, erection and commissioning of 63 units of SG 2.0-114 wind turbines in Osmanabad district of Maharashtra.

PTI, December 20, 2018

Snippets on Wind Power

As Cost of RE Drops, Focus Shifts to Storage Industry

Mr. P.C. Maithani, Advisor, Ministry of New & Renewable Energy, while speaking at the 6th International Conference and Exhibition on Energy Storage, EV & Microgrids has said that the challenge with going purely solar or wind is that solar is available only in the day and wind energy generation can happen between April and September. For instance, when solar panels come under cloud cover, the voltage drops till the cloud passes. We can start by seeing if we can store enough energy for 10 minutes. An ancillary industry for storage can look at developing separate storage for solar and wind and a hybrid system. With the cost of renewable energy coming down and the market potential expanding, an ancillary industry for storage is the need of the hour.

Source: Hindu Businessline, 10th January 2019

India, Nepal Agree to Set Up 'Energy Bank'

India and Nepal have agreed to set up an energy banking mechanism to prevent spilling of electricity when production surpasses demand. The state-owned power utility, Nepal Electricity Authority (NEA), and India's Central Electricity Authority have agreed to the draft guidelines. Nepal would supply electricity to India during the wet season when the domestic output is high and import it back during the winter when domestic production is much lower than the demand. Currently, NEA has been purchasing electricity from India on a need-basis from Bihar, Uttar Pradesh and Uttarakhand under the 'purchase and pay' mechanism. The banking system would involve exchanging electricity for electricity instead of cash.

Source: ET Energy World, December 28, 2018

Wind Generic Tariff in Karnataka Proposed ₹ 2.95/kWh

The Karnataka Electricity Regulatory Commission (KERC) has proposed ₹ 2.95/kWh as the generic tariff for wind projects in the state applicable between April 2019 and March 2020. Once the proposal is finalized, it will become the ceiling tariff for wind tenders in Karnataka for the financial year (FY) 2019-20. This tariff will also apply in cases where payment towards banked energy are concerned. The KERC has proposed a debt-equity ratio of 70:30 for tariff determination. Proposed project costs are ₹ 52.5 million/MW at a CUF of 29 percent. The KERC has proposed interest rates of 11 percent on working capital and an interest rate of 10 percent on term loan.

Source: India Power Trading, Jan 04, 2019

No Future for Gas-based Power Plants in the Country

Mr. Rajnish Kumar, the Chairman of State Bank of India has said that there is no future of gas-based power plants in the country as there seems to be no solution because even when the gas was at around 2½ dollars, even then these plants had viability issue. When these plants were set up, the underlying assumption was that the domestic gas from the Kaveri Basin will be available at a cheap price. Based on that, all these investment decisions were taken. In the current scenario when the gas price is so high and when there are constraints in the supply of domestic gas, it seems that as if we are "groping in the dark. There is no other solution. We have to write off this investment."

Source: ET Energy World, January 04, 2019

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Editor: Dr. Rishi Muni Dwivedi

Photo Feature

Tamil Nadu Global Investors Meet 2019: Seminar on Investment Opportunities in Renewable Energy

At Tamil Nadu Global Investors Meet 2019, held at Chennai Trade Centre, Nandambakkam, Chennai on 23rd and 24th January 2019, a Seminar on Investment Opportunities in Renewable Energy was organised on 24th January from 10.00 am to 11.30 am.

Mr. Md. Nasimuddin, IAS, Principal Secretary to Government, Department of Energy, Government of Tamil Nadu, speaking at the seminar

From Left to Right: Mr. Girish Luthra, Chairman & CEO, Gujarat Environ Protection & Infrastructure Ltd; Prof Rajeev Ram, Professor of Electrical Engineering, Massachusetts Institute of Technology; Mr. P. Thangamani, Hon'ble Minister for Electricity, Prohibition and Excise, Government of Tamil Nadu; Mr. M. C. Sampath, Hon'able Minister for Industries, Government of Tamil Nadu; Mr. Praveen Kumar, IAS, Additional Secretary, Ministry of New and Renewable Energy, Government of India; Thiru Ramesh Kymal, Chairman & MD, Siemens Gamesa India and Mr. Thiru Jayant Parimal, CEO, Adani Green Energy

Snippets on Wind Power

Renewables Overtake Coal in key European Markets

Coal-based power generation was overtaken by wind and solar for the first time in five key European markets last year, according to a recent research by Wood Mackenzie Power & Renewables. The combined share of wind and solar in Europe's largest electricity markets and the UK increased marginally to 17 per cent in 2018, lifting it above coal for the first time.

Source: ET Energy World, January 28, 2019

Vestas Launches New 5.6MW Turbines

Vestas has unveiled a radical new onshore wind turbine platform EnVentus, with its first models featuring a power rating of 5.6MW and rotor diameter of up to 162 metres. It features a medium-speed geared drivetrain, and will be manufactured according to modular principles adopted from the heavy truck industry.

India Calls for Diaspora Role in Developing Renewable Energy Sector

India on January 23, 2019 called upon its diaspora to play a role in boosting the renewable energy sector, with Minister of State for External Affairs V.K. Singh calling for suggestions from the participants at the Pravasi Bharatiya Divas (PBD) -- the Indian diaspora conclave -- on how to develop solar energy.

Source: IANS, January 23, 2019

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