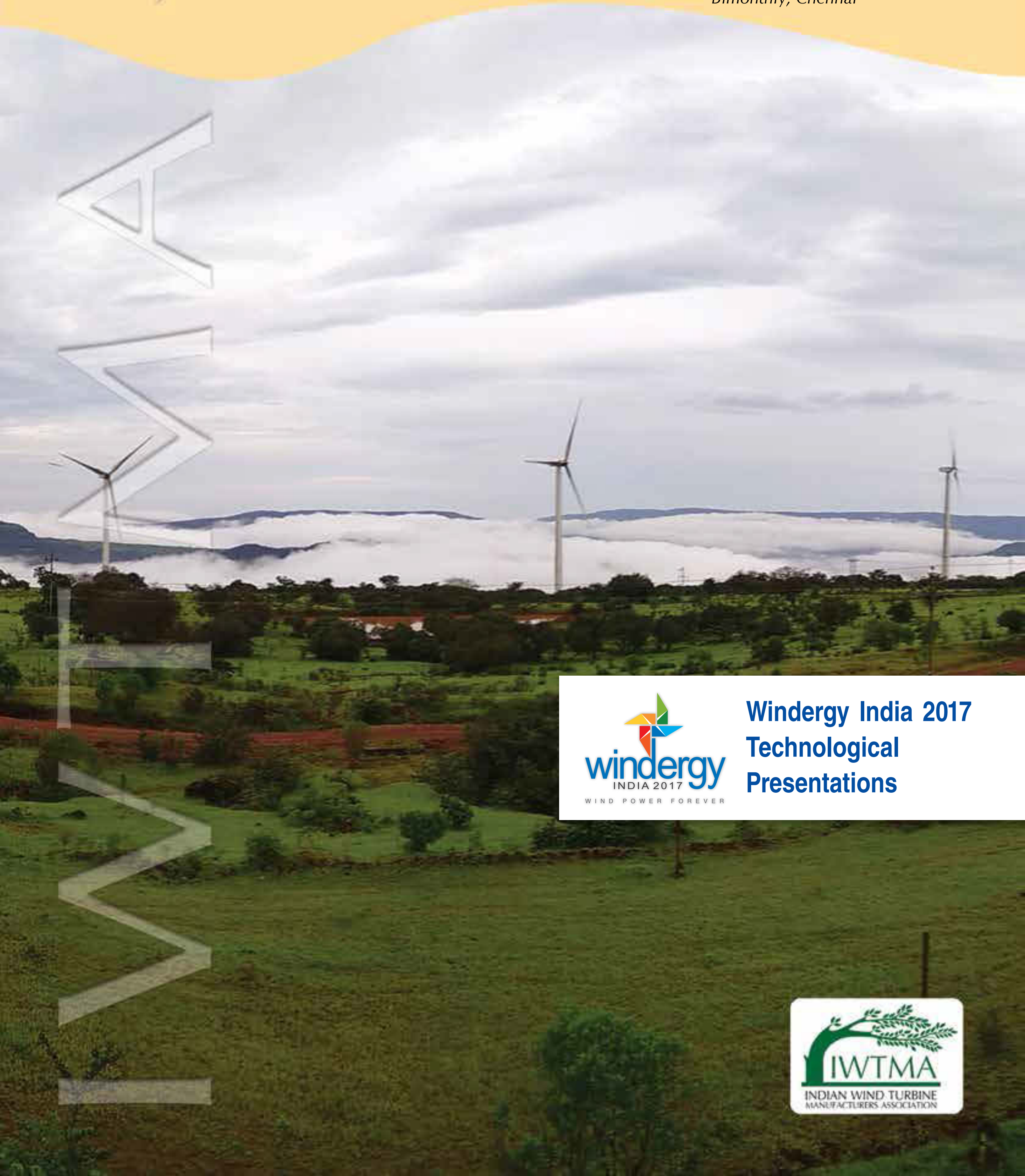
Indian Wind Power

Volume: 3 Issue: 4 October - November 2017 ₹ 10/-
Bimonthly, Chennai



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New Solutions for Wind Turbine Scaling

(Paper presented in Abstract Presentation at
"Windergy India2017 Conference" organised by IWTMA and GWEC)

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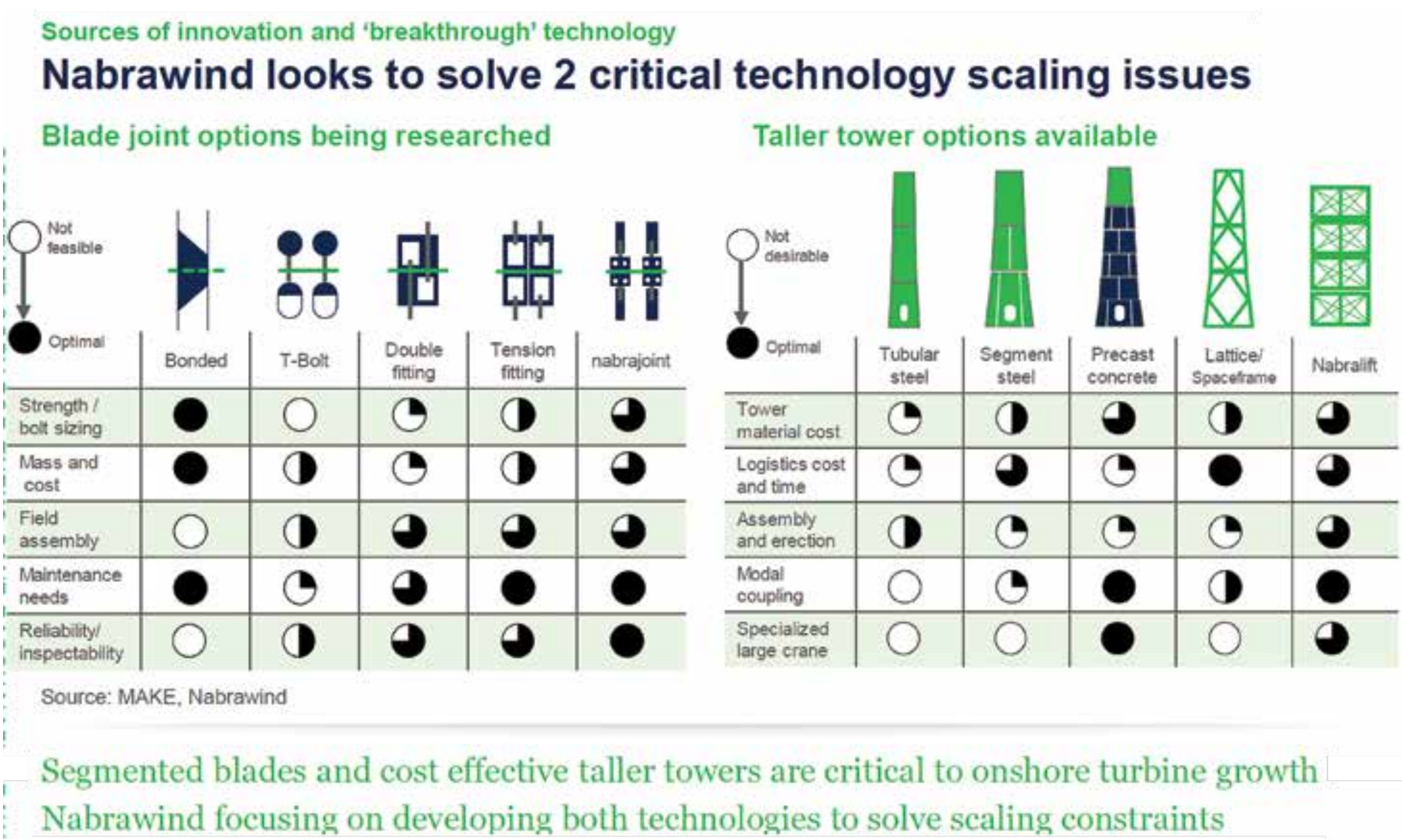
In accordance with the latest trends in the development of the last generation wind turbine generators announced by the leading OEMs, which will move wind turbines to rotor diameters of 150m and total heights above 240m, the transport and installation of these enormous blades and towers presents the next great challenge in the renewable energy industry.

In response to this, Nabrawind Technologies has developed two solutions to resolve the main challenges to the two most important components (both in size and cost) of the wind turbine generator: the self-erecting tower and the joint of modular blade. The potential of these solutions has been noted by major experts in the market.



A Crane-Less Self-Erecting Tower

Towers with heights in excess of 120m are now a reality in all markets, reaching heights of up to 165m in the European market. In 2016, more than 2GW of towers of more than 120m were installed and it is expected this will grow to more than 10GW a year within 5-10 years (more than 15% of the total wind energy market). In fact, major producers of wind turbine generators have included towers with heights in excess of 160m in their catalogues.

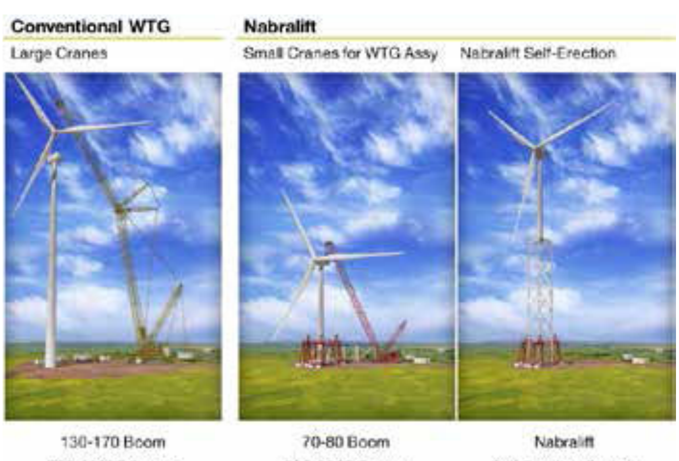
In India, SUZLON is having great success with their tower of 120m, due to this, competing manufacturers are also working toward offering towers of greater heights.

However, the challenges of these large scale towers are widely known: exponential increase in cost, difficulties with transport and/or logistics design constraints, scarce availability of cranes, high mobilisation and rental costs of cranes, increased time required for the installation of the wind farm and lastly risk of resonance oscillations linked to the tower and the rotor speed.

Due to these factors, for several years there have been a variety of proposed alternatives to solve one or another of these problems. However, no solution has been able to solve all problems at once like this new crane-less tower.

The new self-erecting tower consists of two different parts. The upper part of the tower, with a length equal to that of the blade, is a tubular steel tower, which is a conventional technology that is widely recognised and very competitive if the aforementioned barriers didn't exist. In the lower part, it is included a structure with three main columns of approximately one metre diameter, connected diagonally, providing the required torsional and shear rigidity. These columns have a distance between each other between 14 and 18m, which achieves enormous rigidity with weights and costs significantly lower that other solutions.

Its straight profile and constant distance between the tower columns simplifies enormously the self-erection, which is carried out with conventional hydraulic devices widely used in the heavy lifting sector. This self-erection is carried out once the nacelle and the rotor are installed, eliminating the need for large cranes during the installation and operating stage of the wind turbines. The next image shows the differences between the conventional lifting of a wind turbine and the new system.

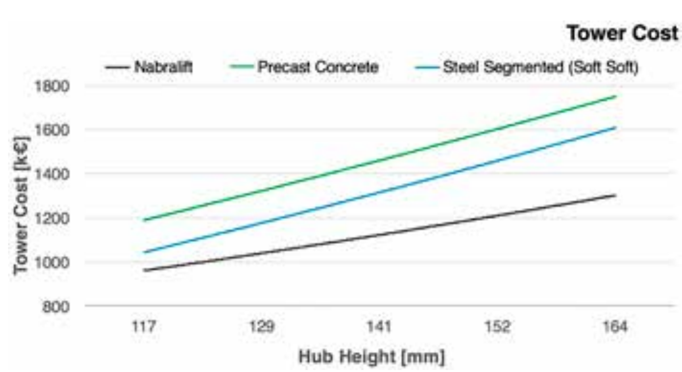


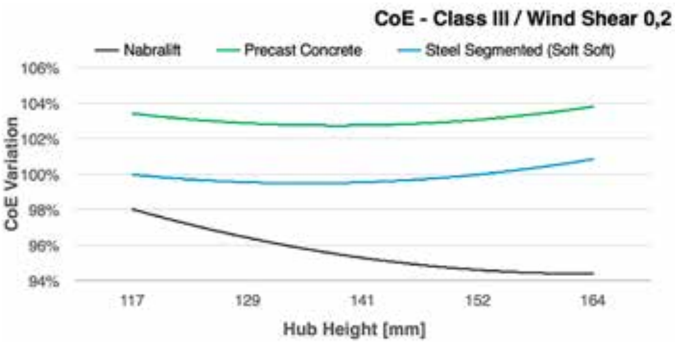
This solution overcomes all the existing problems with large scale towers, as summarised below:

- The logistics of all components can be carried out with standard ISO shipping containers (all components are less than 12m long).
- The installation on site does not require large cranes, hence the cranes required are widely available. In addition to the benefits of not using expensive cranes, the surface required for the installation is also reduced significantly.

- The self-erecting system is dimensioned to work at higher wind speeds than conventional cranes (up to 15 m/s). This almost halves the time lost due inefficiencies when components cannot be lifted using conventional lifting methods. This, combined with the simple tower structure and the use of smaller cranes allows a significant reduction in the time required to install the wind turbine generators.
- The enormous rigidity of the lower part of the tower moves the natural resonance frequency of the tower away from the rotor speed or blade passing frequencies, eliminating the risk of frequency resonance that is an issue with tubular steel towers above 120m in height.
- Lastly, the cost of the tower is influenced in all its components. The foundation volume is reduced between 30-50% due to the use of individual footings with much smaller loads. The lower section of the tower drastically reduces its weight, therefore also its cost. Transport in conventional trucks also minimizes logistical costs, equally reducing installation costs due to the self-erection process without large cranes.

The outcome of these economic advantages is a tower cost-height ratio with a smoother slope than that with other solutions. The result is that a Cost of Energy (CoE) that can be as much as 5 to 8% lower than other types of towers, as shown in the graphs below.





Tower cost evolution and cost of energy in relation to height

In summary, this new self-erecting tower is the most competitive solution in the market to ensure that all latest generation wind turbine generators do not face height restrictions, enabling optimisation of the cost of energy.

A First-Class Modular Blade Joint

The trend towards growing the size of blades is evident. The major wind turbine manufacturers are announcing rotors of more than 150m diameter for new land based wind turbines.

In addition to the above, the idea that blades shall be modular at these sizes is widely accepted within the sector. All wind turbine manufacturers are investing in the development of a solution for large blades segmentation. The key factor in this challenge is finding a mechanical solution with minimal increases in weight and cost.

In the last 20 years, several companies have developed high resistance mechanical joints, including modular joints of blades. Levering on this, it has been conceived and patented a new solution of high resistance that simplifies as much as possible the mechanical components used in the joint.

The joint uses a patented design, with inserts adhered to the blade laminate, with a resistance 30% superior than solutions developed to date, and uses only one bolt to join the opposite inserts on both sections of the blade.

The pre-tensioning of the aforementioned bolts is carried out with a simple and compact system, also patented. The assembly process is entirely automatic and robust, ensuring 100% control of the joints. This process is purely mechanical, avoiding use of adhesives which are highly sensitive to environmental conditions and therefore unreliable. The new connection is also maintenance free and does not require any type of intervention during its service life.

The modular blade joint has been designed to be integrated into any of the market available blades, with minimal design adjustments in the joint area and especially, minimal investment in tooling and equipment. Due to this, existing blade moulds can be utilised to fabricate modular blade versions, coordinating this smoothly with the conventional production processes.

The validation and certification of the joint (currently ongoing with certification authority DNV-GL) is based on an exhaustive testing plan, covering from testing of materials and design details to the validation of a 1:1 scale joint.

This new modular blade joint is without doubt, the definitive and most competitive solution in the market, due to its minimal weight and associated costs, rapid and robust assembly on site, providing maximum reliability derived from its intense validation process.

Imminent Entry to the Market

In 2017 we are finalising the certification process of both technologies. In parallel, it is also closing its first commercial agreements with several major manufacturers of wind turbine generators. Due to this, it is projected for 2018 the supply of the first self-erecting towers as well as joints for the modular blades.