WINDTECH INTERNATIONAL

April/May 2019 Volume 15 No. 3

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A Telescopic Wind Tower With Reduced Environmental Impact

The PERIMA Project

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A prototype of a telescopic pole for wind energy production with low environmental impact and its lifting system for a 60–250kW turbine and a height of 30 metres have been designed and manufactured. A telescopic tower, which is raised and lowered by automation or by remote control, allows differentiation of the presence of the generator within the landscape over time. The research target is the optimal design of the telescopic coupling, the maintenance of the preload, the rotational decoupling, the pairs of sleeves, the pegs and the bushes of the jack-up lifting system. All the components of the wind tower have been preliminarily analysed through finite element method stress computational analysis. The prototype was installed in Caltanissetta, Italy, and successfully tested.

Introduction

The main drawback of wind farms is their significant environmental impact, mainly in terms of landscape alteration. The discomfort generated by wind farms is worsened by the persistence of the facilities even during periods of time when the demand for electricity is absent or the benefit from the production is less than the social cost of the environmental factors. An important line of research and industrial development is therefore the creation and production of wind power plants that have a lower environmental impact during the rest period. This can be done with the use of a tower which can be lifted and lowered easily and with high frequency. The currently available technology for the lifting and the lowering of the towers for wind turbines is given only by tipper masts in the mini-turbines sector and by hydropneumatic telescopic masts in the micro-turbines sector.

PERIMA Project

The University of Palermo, together with the partners of project PERIMA (Produzione Eolica con Ridotto IMpatto Ambientale, partners Elettrocostruzioni, Onda, Imam, University of Palermo, IEMEST Research Institute) of the 4.1.1.1 PO FESR Sicily 2007/2013 programme, has developed a special lifting system based on the pre-drilling of a deep foundation pit equal to the height of the pole but of a much smaller diameter. The system designed in 2015 was produced, assembled and installed in 2016 at the headquarters of the project's lead partner. The telescopic tower can be raised or lowered in less than 20 minutes and is designed for a 60–250kW turbine and a height of 30 metres. The tower prototype, which has a diameter of about 1 metre, is illustrated in Figures 1 and 2 and was lowered and raised several times up to the end of the project in 2017.

Innovations in the Telescopic Tower

The device is made from four main parts: a foundation, a telescopic tower, a lifting system and a wind turbine with two blades. The novelty of the new approach can be summarised in the following points: 1) sleeve joints with inclined coupling surfaces, 2) the presence of an internal thrust piston, 3) a newly designed lifting jack-up system that is fast and safe, 4) Teflon plates which realise axial sliding, and 5) the presence of a preloading mechanism of the structure that also realises the decoupling of the rotation of the tower from that of the piston during the lifting. The novel telescopic system retains all the advantages of the available technologies: the tipper masts, or tilt-up masts, and the telescopic towers based on hydropneumatic systems but with a much higher payload and working head capacity.

Foundation

The foundation needs to 1) secure the stability of the tower

Figure 1. PERIMA prototype with telescopic tower in its lowered position

Figure 2. PERIMA prototype with telescopic tower in its lifted position

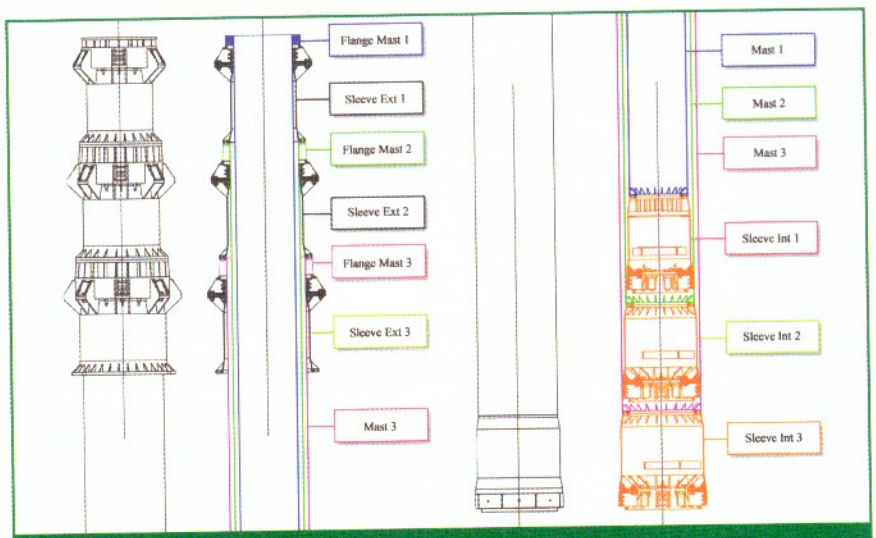

Figure 3. Schematic draft of the coupling between masts and sleeves: (left) upper part of the masts, (right) lower part of the masts

at any time and 2) house the tubes of the telescopic tower at rest. The depth is calculated so as to have, at rest, an elevation of the wind turbine of a few metres above the ground. The adopted foundation is given by a tubular shaft made by a ring of reinforced concrete piles clamped at the top through an annular edge beam of reinforced concrete and 2 steel cylinders where hollow spaces are saturated with cement mortar. The system allows lifting by means of tubular elements connected by sleeves and a piston that pushes the plate below the mast of smaller diameter.

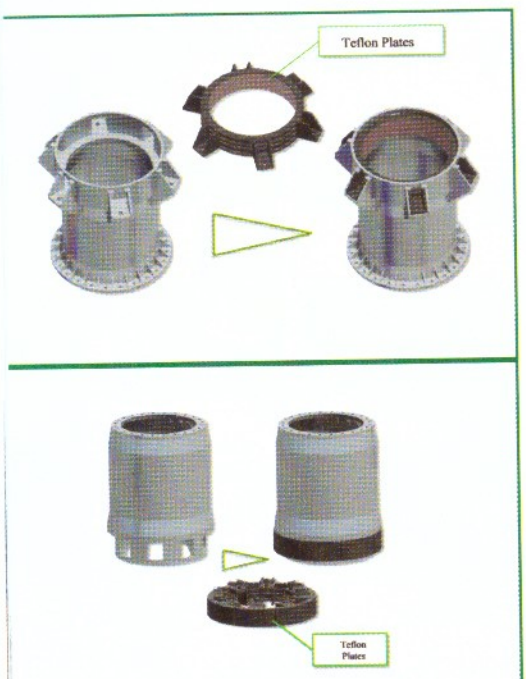

Figure 4. Outer sleeve (top) and inner sleeve (bottom)

The lower outer sleeve, which forms the base of the tower, can itself be housed below the ground level.

Telescopic Tower

The telescopic structure is composed of three tubular elements in steel – mast 1, mast 2 and mast 3 – of increasing outer diameter, in order to be able to enter one inside the other during lowering (Figure 3), and equipped with perforated upper and lower flanges for the assembly of a six-sleeve junction (three internal and three external) (Figure 4). The axial sliding is guaranteed by the implementation of a system of Teflon plates with a curved profile. Only the outermost inner sleeve slides on the inner wall of the foundation. The Teflon plates, both in the external sleeves and in the inner sleeves, are supported by a steel structure bound to the sleeves by screws and nuts to allow possible adjustments. Each sleeve has a truncated conical shape for the lower part and an external shape complementary to it for the upper internal part. Starting from the lowered position, the innermost sleeve is raised by the lifting piston by means of the jack-up system and slides with respect to the immediately outermost sleeve until the outer surface of the truncated cone does not reach the inside of the shape complementary to it placed on top of the next mast. At that point the inner sleeve drags with it also the next external one. The diameter of the truncated cone is smaller than the internal diameter of the next outer sleeve, so that the sliding between the two elements can take place despite the typical tolerance of commercial tubes (0.5–1cm), but it is also sufficiently greater than the top diameter to prevent an unwanted locking of the sleeves at the time of descent. The mechanism is repeated for all the sleeves until the outermost sleeve blocks the further raising of the tower. At this point the piston is blocked by means of an appropriate safety mechanism and the presence of an elastic element – a high-load air spring – which ensures conservation of tension and then a rotation lock by friction.

Lifting System

The lifting system of the prototype is inspired by the lifting system of the jack-up rigs, a type of mobile platform that consists of a buoyant hull fitted with a number of movable legs, capable of raising its hull over the surface of the sea. A lift jack-up actuated by hydraulic pistons actuates the piston of the same length of the telescopic tower in the extended configuration (Figure 5). The piston is a tube with many holes, where the pegs of the jack-up are placed before lifting or lowering the piston. When the telescopic tower is at rest, the piston is housed in a smaller diameter

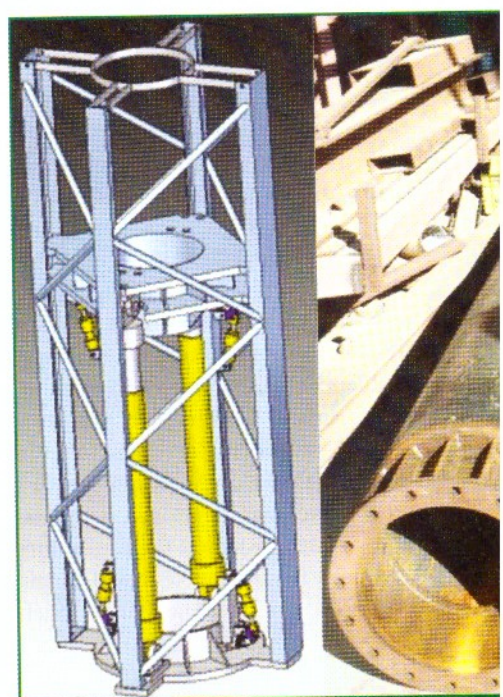

Figure 5. Lifting system

shaft. In the prototype, the well is deep at about 30 metres. The jack-up lifts the piston with regular runs of 0.85 metres and allows locking of the tower after the final level of compression of the air spring is reached.

Wind Turbine

The wind turbine installed on the telescopic tower is a Libellula 55kW produced by Aria. At a wind speed of 3.0m/s, the wind turbine starts its work. The cut-out wind speed is 25.0m/s. The rotor diameter of the Aria Libellula 55kW is 18.0 metres. The rotor area is 255.0 square metres. The wind turbine is equipped with two rotor blades. The maximum rotor speed is 95.0rpm. The Aria Libellula 55kW is fitted with a parallel gearbox with 2 stages.

Conclusions

A prototype of a telescopic pole for wind energy production and its lifting system for a 60–250kW turbine and a height of 30 metres have been designed and manufactured. The pole is raised and lowered by automation or by remote control, allowing differentiation of the presence of the generator within the landscape over time. Each component of the system was designed for the realisation of the prototype, which was installed in Caltanissetta, Italy, and successfully tested. ■

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