Chapter 29
Extensible Wind Towers

Marco Sinagra and Tullio Tucciarelli

Abstract The diffusion of wind energy generators is restricted by their strong landscape impact. The PERIMA project is about the development of an extensible wind tower able to support a wind machine for several hundred kW at its optimal working height, up to more than 50 m. The wind tower has a telescopic structure, made by several tubes located inside each other with their axis in vertical direction. The lifting force is given by a jack-up system confined inside a shaft, drilled below the ground level. In the retracted tower configuration, at rest, tower tubes are hidden in the foundation of the telescopic structure, located below the ground surface, and the wind machine is the only emerging part of the system. The lifting system is based on a couple of oleodynamic cylinders that jack-up a central tube connected to the top of the tower by a spring, with a diameter smaller than the minimum tower diameter and with a length a bit greater than the length of the extended telescopic structure. The central tube works as plunger and lifts all telescopic elements. The constraint between the telescopic elements is ensured by special parts, which are kept in traction by the force of the spring and provide the resisting moment. The most evident benefit of the proposed system is attained with the use of a two-blade propeller, which can be kept horizontal in the retracted tower configuration.

M. Sinagra (✉) · T. Tucciarelli
Dipartimento di Ingegneria Civile, Ambientale, Aerospaziale, dei Materiali, Università degli Studi di Palermo, viale delle Scienze, edificio 8, Palermo, Italy
e-mail: marco.sinagra@unipa.it

T. Tucciarelli
e-mail: tullio.tucciarelli@unipa.it

T. Tucciarelli
Sezione di Idraulica e efficienza delle risorse, Istituto Euro-Mediterraneo di Scienza e Tecnologia, Via Emerico Amari, 123 90139 Palermo, Italy

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29.1 Introduction

The occurring strong increment of the wind velocity along with the elevation requires the wind turbines to be located in exposed places, so that wind turbines and their towers have often a significant impact on the country landscape. This impact, along with the turbine noise and the possible inference of the blades with the bird life is the major issue against further construction of wind energy plants.

A partnership of Italian companies and research institutes are starting the PERIMA (Produzione Eolica con Ridotto IMpatto Ambientale) project, co-funded by 2007–2013 Regional Operational Programme of the European Regional Development Fund, which aims to develop a telescopic tower for medium power wind turbines, able to move up and down in a short time and without the use of any external machinery. The project starts from the observation that in many locations wind turbines produce significant power only during part of the total yearly time. In the remaining time a cheap and fast removal of both the turbine and the tower would not provide a significant reduction of the total produced energy. For example, in several Mediterranean locations along the coast, most of the energy production occurs in winter, when most of the tourists are missing. In other cases most of the energy could be produced in short periods of time, when weather conditions make the relative impact of the plant on the surrounding environment much less severe.

A telescopic structure, made of several tubular elements with different diameters moving inside each other, has been envisioned as the best solution for the addressed problem [1]. An alternative choice is the tilt-up tower [2]. This technique has been already adopted for towers with small height, maximum 20 m, but has the inconvenient of (1) leaving a significant impact inside the tower area after his reposition, (2) being difficult to apply for high towers.

The main challenges to be faced by the project are (1) the need of an efficient lifting system, able to rise a load of the order of 500 kN for a displacement of tens of meters, (2) the construction of a junction system automatically linking the tubular elements when the tower is fully extended. The use of a simple oleodynamic actuator is prevented by its cost [3], while the junctions of the elements are required to balance all the momentum generated by the horizontal forces acting on the turbine, but must be armed and disarmed easily, without the need of a direct human action.

In this paper the authors describe the proposed lifting system and linking device with reference to a wind tower of 30 m, supporting a 60 kW wind generator (Fig. 29.1).

29.2 The Telescopic Tower

The length of each tubular element can be set equal to the maximum length allowed for trunk transportation. This length is usually about 10 m. In the example of Fig. 29.2 the tower is split in four elements, one of them kept fixed below the ground level. Each tubular element has two junctions at the ends, which are better

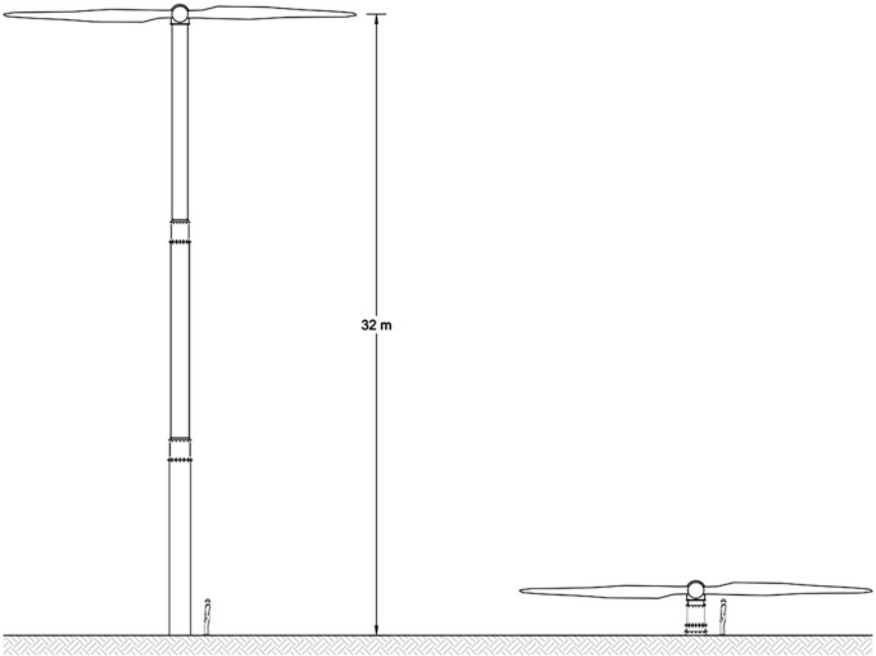
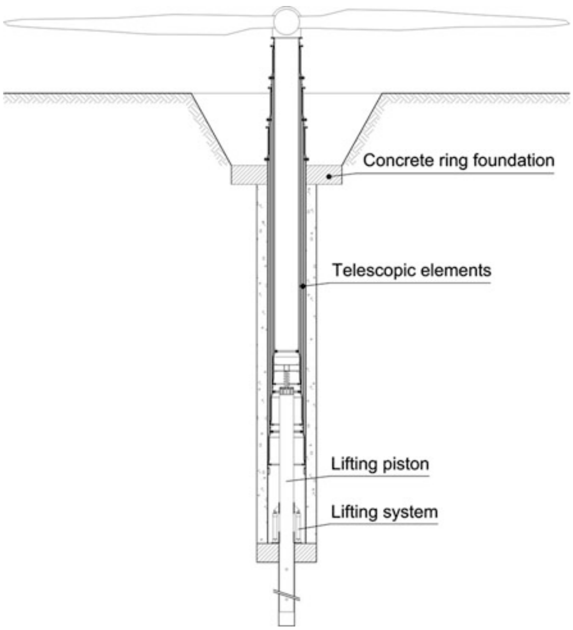


Fig. 29.1 Telescopic tower: **a** tower extended; **b** tower retracted

Fig. 29.2 Section of telescopic tower



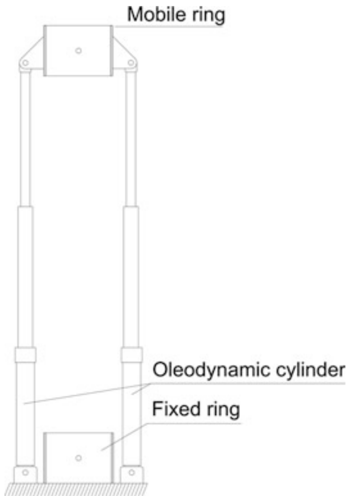


Fig. 29.3 Lifting system

described in the following section, and slides on the larger element during the rising time through two sets of small carts. One set of carts is fixed on the external side of the lower junction of the moving element, the other one is fixed on the internal side of the upper junction of the larger element. The carts are designed to provide only a small momentum during the rising time, when the blades of the wind generator are kept fixed. A shaft is drilled to host all the tubular elements. All the elements, at rest, are laid on a metallic ring located 1–2 m above the shaft foundation. In the example of Fig. 29.2 the outer diameters of the telescopic elements, from top to bottom, are 0.8, 0.94, 1.08 and 1.22 m (Fig. 29.2). The thickness for all tubes is equal to 10 mm.

The tower lifting takes place via a piston, which is a pipe with a diameter smaller than the minimum wind tower diameter and a length a bit greater than the length of the extended telescopic structure, which runs along a borehole drilled below the tower foundation. The movement is transferred by the piston to the innermost tubular element, which drags the larger one when the lower junction of the innermost element meets the upper junction of the larger one. Observe that, at work, the load on the tip of the piston is equal at least to the total weight of the tower. Unless horizontal control is given to the piston displacement along its extension, structural stability condition has to be verified.

The lifting of the piston is guaranteed for a length of 1–2 m by a couple of oleodynamic actuators. The main case of each actuator and the end of its arm are bound to a pair of rings (Fig. 29.3). Both rings can be either bound or free from the piston by the extension or the retraction of small cylinders entering holes excavated inside the piston (jack-up system). The distance between two holes in the vertical direction along the piston is equal to the maximum displacement of the arm of the actuators. An automatic system guarantees that one of the two rings is always bound to the piston, either to drop the arm after each lifting step or to lift the tower during the lifting (or the dropping) step.

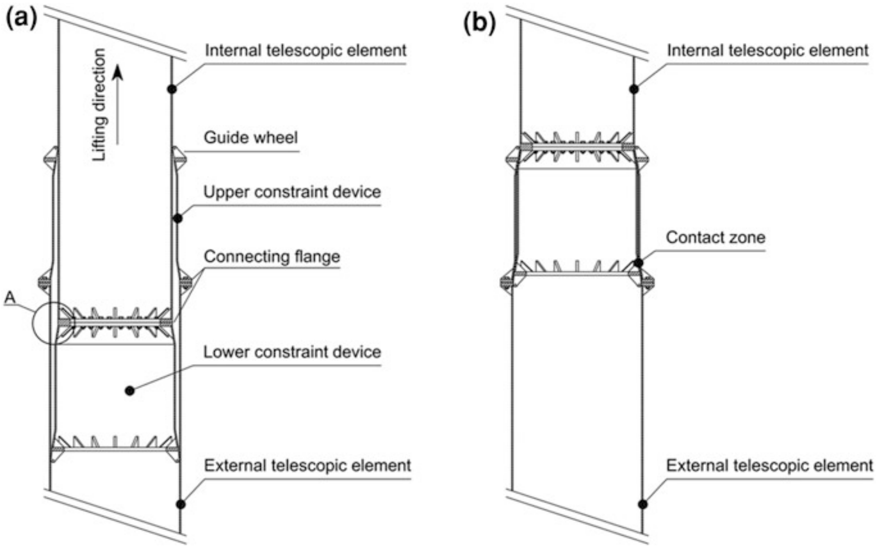


Fig. 29.4 Joint system and guidance system; **a** during lifting, **b** after lifting

29.3 The Tubular Element Junctions

The two cart sets fixed on each element junction balance the momentum given by the wind force only during the lifting (or dropping) time, but the same momentum has to be balanced during the working time, or even when the wind generator is at rest, but strong wind forces act on the tower. This requires a robust junction system and a self-locking device. Each proposed junction has two steel elements with a truncated cone shape [4] and a relatively small height (0.15 m in the example). The larger radius of the smaller element is equal to the smaller radius of larger one and the two elements are spaced out by a cylinder. The cylinders of the mating junctions have the same height, but a bit different diameter, such that the smaller one can move inside the larger one. After the inner tubular element is raised up, the smaller and the larger cone shaped elements of the two junctions mate (Fig. 29.4). The reaction forces will have two components; the vertical one will transfer the lifting force to the larger element, the horizontal one will provide the momentum required to balance the momentum of the external forces (Fig. 29.5). Observe that, to avoid the instability of the piston, an elastic element like a spring must be placed between its tip and the base of the innermost tubular element (Fig. 29.6). This is because part of the vertical component of the junction reaction, due to the external momentum, could be otherwise balanced by the piston itself. In the proposed example the cone shaped elements are disposed at a distance equal to 0.85 m. The slope of the cone must large enough to guarantee a reaction component tangent to the surface small enough (with respect to the normal one) in order to avoid the scroll of the two junctions. On the other hand, the slope must be small enough to

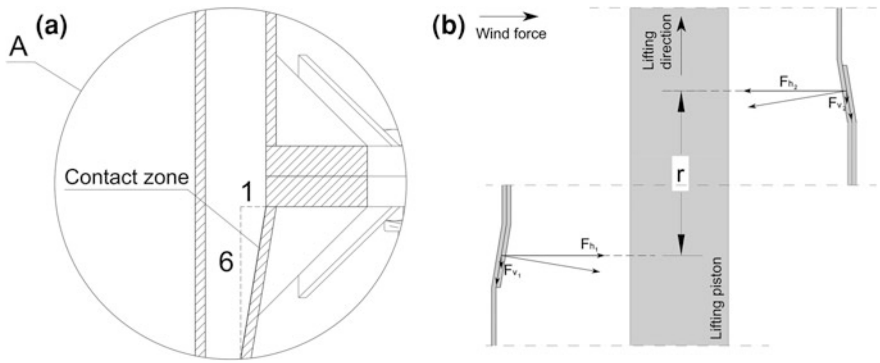
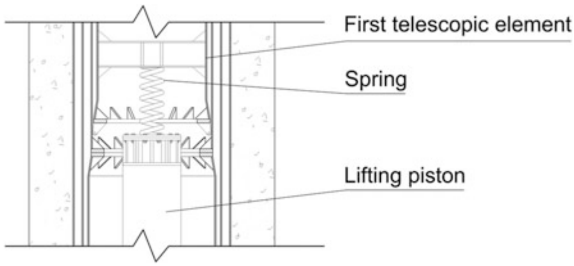


Fig. 29.5 Junction details **a** slope of the contact area; **b** reaction forces scheme

Fig. 29.6 Detail of the lifting spring



allow a large tolerance between the cylinder diameters, as well as to avoid the block of the cone mating during the tower drop. A ratio 1:6 seems to be a good compromise.

The force provided by the elastic element must guarantee a tensile strength in all the junctions. Using standard steel with a standard friction coefficient, even a force almost equal to the tower weight should guarantee the adhesion of the mated junctions. On the other hand, the variability of the wind forces could provide compressive forces on the top of the tower and a security margin is required.

29.4 Conclusions

This work has shown the innovative proposal of a telescopic wind tower, which is well located inside the international technological research oriented to renewable sources. The main strength of this system is its construction with existing components commercially available, a feature that makes it potentially competitive on a commercial level. The cost increment deriving from a larger tower complexity is compensated by a significant reduction of transport and mounting costs and civil works for road construction, as well as by a significant increment in the number of possible installation sites. Finally, observe that the drilling works necessary for the lifting system can be used also to put a filter and a water pump immediately below the shaft foundation. For a plant that needs electricity and water, such as a farm, the cost of drilling could be afforded only once for both needs.

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