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Towards the sustainability in the design of wind towers

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Abstract

Wind farms are both a renewable energy production alternative and a profitable economic enterprise. At the same time these groups of wind towers can be a social-friendly solution if they solve challenging demands from the society such as integration in landscape, aesthetics, low noise nuisances...

This paper presents part of a complete research project that was carried out between 2009 and 2015. First this article presents a new wind tower proposal that has been designed to reduce these social impacts as well as satisfying environmental aspects, economic requirements and boundary conditions such as height, turbine power, soil conditions... This proposal is composed of precast concrete modules joined with high-resistance steel bars that define a post-tension structure. These components define an attractive and transparent tripod that is transversally reinforced with steel profiles. This system holds the Spanish patent "Support structure to wind turbines, number ES 2 319 709 B8" and aims to build 100-120m high towers. At this height there is better wind quality and large turbines of 3 MW can be installed.

Second, a sustainability assessment of this new hybrid wind tower has been carried out in order to evaluate its social, environmental and economic impacts compared to other solutions. Steel lattice structures, steel tubular systems, in situ concrete towers and precast concrete structures are the alternatives for wind farms that have been considered. MIVES, a MCDM methodology based on the value function concepts has been used to do this assessment, which has relied upon seminars of experts. This sustainability assessment enabled the identification of the aspects with the lowest sustainability index. These are the maintenance and deconstruction costs and for occupational hazards. Now these weak points can be corrected in the process of bringing the patented technology to market.

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1. Introduction

Among the different renewable energy production alternatives, wind farms are a profitable economic solution with a promising future ahead. In this sense, the cumulative wind power capacity until 2015 has been 435 GW [1] band its share of renewable energy production is expected to increase from 9% in 2013 to 41% in 2030 [2]. However, to achieve a bright future its social acceptance must keep growing and wind farms must be optimized in numerous aspects such their efficiency [3] and location [4] among others.

Wind farms are mainly composed of wind towers that are distributed within the onshore or the offshore limits depending on the kind off Wind Park. Wind towers have two main elements, the turbine and the tower. Numerous types of turbines can be installed on wind towers to generate important amounts of electricity up to 7.5 MW per turbine. The most common type is the three-bladed horizontal-axis turbine, which has a rotor and a nacelle among other components.

The tower elevates the turbine to the design height and transfers the loads to the foundation. Most towers are constructed using concrete and/or steel as the resistant materials. The main steel solutions are the lattice and the tubular towers. The concrete alternatives have steel reinforcements and mainly differ depending on their onsite or prefabricated building processes. The hybrid solutions combine parts built using steel and parts constructed using reinforced concrete. The turbine industry and the market itself have designed application ranges for these different solutions depending on their height. Table 1 presents the main construction alternatives for wind towers and some of their applications, strengths and weaknesses [5].

Table 1. Applications, strengths and weaknesses of wind towers main construction alternatives.

		Height (m)	Base Ø (m)	Weight/height (t/m)	Strengths	Weaknesses
Steel	Lattice	60-160	Unlimited	2-3	Easy transport & quick installation	Vulnerable joints & low fire resistance
	Tubular	60-120	3.0-4.5	2-5	Less material & optimal transport for h<80m	High transport and assembly costs for h>80m
Concrete	Onsite	60-115	3.0-8.5	8-19	Monolithic, durability & stiffness	Weather conditions vulnerability
	Precast	80-120	3.0-5.0		Quick installation	Vulnerable joints & high transport and assembly costs
Both	Hybrid	80-146	3.0-5.0	3-15	Expected to solve weaknesses of previous alternatives	In experimental stage

Lattice towers are composed of steel sections bolted and/or welded together on site. This alternative can solve different heights, from 60 m to, for example, the 160 m reached by the tower in Laasow, Germany [6]. The main advantage of lattice towers is their competitive price due to the optimization of the material used to build them, its easy transport and quick installation. Nevertheless, for heights greater than 80 m, which are the scope of this research paper, this steel solution has fewer weaknesses and is less competitive. For these more than 80 m heights the market is dominated by tapered tubular towers because of their superior optimization in transport and material [7].

Onsite concrete alternatives [8] use passive reinforcement to reduce tensile stress. In contrast, precast concrete solutions [9] use prestressing to connect the precast modules and, in addition to this active reinforcement, steel bars can be used to increase the concrete's resistance to cracking. Some towers use both technologies [10] and towers may even be precast onsite if the number of towers justifies the cost.