On the structural behaviour of variable-geometry oval-trajectory Darrieus wind turbines

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Abstract

We developed a computational model based on a finite-element mixed formulation with quadratic isoparametric beam elements. We applied this model to the analysis of a blade-wagon: a novel structure characteristic of an innovative concept in wind-power called VGOT Darrieus turbine. We studied the structural behaviour of its main components: chassis, suspension and blade, using combinations of beam/bar elements in an appropriate assembling. We defined a set of parameters to characterize the structural behaviour which help to understand the contribution of the different components and assist the process of redesign.

1. Introduction

It is a fact that due to economics-of-scale reasons cost effectiveness of wind turbines increases with size. During the last 25 years the size of the state-of-the-art wind machine has been increasing systematically but the actual technology of horizontal-axis wind turbines would ultimately reach its limits. Very large sizes would create a number of gigantism problems in rotor design and low rotational speed associated with large radii would complicate the coupling with the electrical generator. Besides, there are geographical regions (like Patagonia in Argentina) characterized by a vast wind resource. Mean speeds in some areas double those recorded at European locations for which commercially available high-power wind turbines were designed. Regarding that the energy carried by a wind stream depends on the cube of its speed, those regions offer an enormous potential in terms of energy resources. Hence, it is worthwhile to explore innovative concepts in extra-large wind-power plants to overcome the size limits of the actual wind-power technology and being able to exploit the renewable energetic potential that high-speed regions offer. To this end, an innovative concept of wind turbine based on the Darrieus-type rotor had been introduced [1].

In a traditional Darrieus turbine, the blades rotate around a central vertical axis. In the VGOT (variable-geometry oval-trajectory) concept proposed in Ref. [1], each blade instead of rotating around a central vertical axis slides over rails mounted on a wagon formed by a reticulated structure supported by standard train bogies (see Figs. 1 and 2). Each wagon contains its own electrical generation system coupled to the power-wheels and the electricity is collected by a classical third rail system [2,3]. With the VGOT design, if we kept constant the velocity of the wagons (i.e. the tangential speed of the blades), we can increase the area swept by the blades (and hence the rated power of the plant) without the low-rotational-speed problems associated to a classical Darrieus rotor of large diameter. The blade-wagon elements of a VGOT Darrieus, not being solidly affixed to a central axis, could move following a non-circular trajectory (see Fig. 3). For certain locations where the compass rose shows a preferential direction it is possible to optimize the energy-conversion efficiency of the entire plant by increasing the portion of transit perpendicular to the direction of the incoming wind. Along the perpendicular tracks, the blade generates the higher output-power, while along the portions where the trajectory is in-line with the incoming wind the blade-wagon not only does not produce energy but also even consumes it taking power from the rest of the plant to keep on moving. Thus, extending those portions of the path perpendicular to the wind by the addition of straight tracks the overall energy-conversion efficiency of the plant increases. The idea of mounting a blade on a wagon with the aim of generating electricity has been proposed