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NUMERICAL EVALUATION OF A VERTICAL-AXIS WIND TURBINE CONCEPT APPLICABILITY FOR SITES WITH REDUCED WIND POTENTIAL

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Horizontal-axis wind turbines (HAWT) are, currently, by far, the most common and widely applied turbine type, particularly for machines beyond a certain size and power capacity. There are very good reasons behind this, the most prominent being their high aerodynamic efficiency (having a power coefficient above 0.4, and even up to 0.45 for the large-scale machines). The continuous advancement of composite materials technology and the tremendous progress made in the design of special purpose blade section shapes (airfoils), with controlled stall characteristics and insensitivity to leading-edge contamination, have contributed decisively to this outcome. Nevertheless, the associated design difficulties and the production and installation costs of HAWTs restricts their viability to sites with medium-to-high wind potential.

Although vertical-axis wind turbines (VAWT) are inferior in terms of wind energy conversion efficiency, the actual performance of aerodynamic lift based types (for example, Darrieus, Gyromill, Gorlov) is quite close to HAWTs (power coefficient can reach and even exceed 0.35 for large turbines). They also offer several notable advantages, in general, when compared to the horizontal-axis solution: a) consistent operational response and performance with respect to wind direction, eliminating the need for complex mechanisms and motors to orient the rotor and pitch the blades, b) gearbox and generator positioning at ground level, which drastically reduces suspended mass, lowers tower root bending moment, facilitates installation and maintenance operations and reduces overall costs, c) very simple design, with low production and installation costs, and much easier to recycle due to materials used for manufacturing.

The ability of VAWTs to operate in difficult conditions, like slow, irregular winds, close to the ground or flow obstacles, makes them a very much acceptable alternative for HAWTs in such cases. This also considerably expands the applicability of wind turbines as renewable energy sources, and particularly for reduced wind potential locations. Moreover, recent studies reveal that it is possible to operate VAWTs in close proximity, such that a considerable increase in energy output is obtained, for an entire range of relative positioning – which is a well-known issue for HAWTs, i.e. wake-induced losses. Consequently, a higher density of machines might be possible for a given site, offering the opportunity to raise the total energy output of wind farms.

Aerodynamic drag based, or mixed (drag and lift based) VAWTs (like Savonius, Lenz, combined Savonius-Darrieus, etc.) are also becoming more popular, primarily due to their simplicity and very low cost. They, generally, are significantly less efficient (below 0.3, power coefficient); however, they are also much better adapted for operating in low winds, and have very good selfstarting characteristics.

A numerical investigation of such mixed VAWT concept was performed, with the purpose of establishing its feasibility for reduced wind potential implementations. In order to reduce the overall computational effort, since VAWT simulation requires unsteady methods, a simplified two-dimensional modelling approach has been used. The approach does tend to overestimate slightly the machine performance, by neglecting the blade tip losses and other three-dimensional effects, but it can capture very well the local qualitative and quantitative time-dependent structure of airflow around the blades and the spinning rotor.

Keywords: vertical-axis wind turbine, numerical simulation, computational fluid dynamics

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