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Review

Experimental study on a Savonius wind rotor for street lighting systems ☆

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HIGHLIGHTS

- Experimental tests on different configurations of a Savonius rotor were performed.
- The power coefficient were found not dependent on Reynolds number.
- The influence of some design parameters and external elements were investigated.
- Helical step and elements as grids and posts affect the power coefficient.
- The maximum power coefficient of 0.25 was achieved.

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ABSTRACT

This paper investigates the aerodynamic performance of a Savonius vertical axis wind rotor to be used in an innovative lamppost. The wind generator studied is the main part of a public lighting system (a street lamp) powered by both aeolian and solar renewable energy sources. This study is aimed to analyze the effects of different construction solutions on rotor performance. Experimental dynamic tests were carried out on a 1:1 rotor model in the Environmental Wind Tunnel (EWT) of University "Politecnica delle Marche" (UNIVPM); tests were performed at different wind velocities and for different construction combinations. The results obtained confirmed that, in the tested range 2–3.3 × 10^5, rotor performance does not depend on the Reynolds number. Tests also showed that the presence of end plates and blade overlap increases the power coefficient $C_{P,max}$, while the presence of external grids and structural posts has negative effects on rotor performance. The best results were obtained for a configuration having a helical rotor with a 105° twist, open blade overlap and end plates.

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Nomenclature

A	rotor swept area (m^2)
A_t	total frontal area (rotor + frame) (m^2)
a	overlap distance between buckets (m)
c	bucket chord (m)
C_P	power coefficient
C_T	torque coefficient
C_{TS}	static torque coefficient
D	rotor diameter ($D = 2R$) (m)
D_{ep}	end plate diameter (m)
d	shaft diameter (m)
H	turbine height (m)
l	lever arm length (m)
P	power (W)
R	rotor radius (m)
Re	Reynolds number
s	spacing distance between buckets (m)
S	test section area (m^2)
T	torque (N m)
v_∞	free stream velocity (m s^{-1})
v	reduced section velocity (m/s)

Greek symbols

ϵ	blockage factor
λ	tip speed ratio
λ_c	tip speed ratio at witch $C_{P,max}$ occurs
ν	air kinematic viscosity
σ	standard deviation
ω	angular velocity (rad/s)
θ	position angle (°)

Subscript

max	maximum value

1. Introduction

The last decades have been characterized by a growing interest in environmental issues and consequently in energy topics. Several researchers have dedicated their attention to study alternative energy production sources highlighting that the use of renewable energies and smart energy production systems can effectively contribute to the reduction of environmental impact and to greater energy efficiency. Following this line, a smart lamppost powered by renewable energy sources was developed at University "Politecnica delle Marche" (UNIVPM): the basic idea was to develop a system to be used in urban environments, in network or standalone configurations. The street light proposed is powered by both solar and wind energy: the former is supplied by a photovoltaic panel placed on the upper end of the lamppost, the latter by three vertical axis wind rotors (VAWT) inserted, in line, along the support structure (Fig. 1). The concept of using different energy sources derived from the aim to design a standalone system able to have several days of self-sufficiency and the consideration that on a windy day the sky is normally expected to be cloudy and photovoltaic production low, while on a sunny day wind velocities are expected to be low and so is aeolian production. By combining both energy sources the potentiality of a standalone system could be extended [1].

The choice to use a Savonius wind rotor derived from several positive considerations: it is very simple to build, economic, compact and has low noise emissions. Besides, it works with turbulent and fluctuating wind conditions typical of urban environments, it has a high static torque (self-starting wind turbine), it requires little maintenance and could be easily integrated into the design of vertical structures. On the other hand the power performance of a Savonius rotor is lower than that of a three blade horizontal axis wind turbine, therefore it is not suitable for significant energy production. Many authors have studied the Savonius wind rotor, obtaining maximum power coefficients in the range 0.10–0.25. As just mentioned, these are low values if compared to those obtained with other types of wind generators [2,3]; this reason

Fig. 1. The UNIVPM prototype of the experimental street lamp powered by renewable sources.

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