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Optimum design configuration of Savonius rotor through wind tunnel experiments

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A B S T R A C T

Wind tunnel tests were conducted to assess the aerodynamic performance of single-, two- and three-stage Savonius rotor systems. Both semicircular and twisted blades have been used in either case. A family of rotor systems has been manufactured with identical stage aspect ratio keeping the identical projected area of each rotor. Experiments were carried out to optimize the different parameters like number of stages, number of blades (two and three) and geometry of the blade (semicircular and twisted). A further attempt was made to investigate the performance of two-stage rotor system by inserting valves on the concave side of blade.

1. Introduction

In recent years, an interest in wind energy has been growing and many researchers have attempted the development to introduce cost-effective, reliable wind energy conversion systems all over the world. In practice, however, there are many difficulties, to introduce the wind turbine into the community because of less wind energy source, profitability, noise emission, etc. Therefore, the decentralization or local clusterization of renewable energy plant made it attractive not only to developing area, where a lot of people do not yet have access to conventional electricity service, but also to an urban area where one can make better living space for future generation (Shikha et al., 2003; Grinspan et al., 2004; Menet, 2004).

This project was undertaken to optimize the design configuration of Savonius rotors with the expectation that this inherently simple vertical axis machines could be manufactured at low cost,

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Nomenclature

A	projected area of the rotor (m^2)
A_R	aspect ratio of blade (h/d)
c	chord of the blade
d	diameter of cylinder constituting the paddles (chord)
C_p	power coefficient
D_f, D_o	diameter of the end plate (m)
D	diameter of rotor (m)
e	gap between the two blades: main overlap
e'	gap between the two blades: second overlap
h	height of the blade (m)
N	rotational speed of the rotor (RPM)
P_s	shaft power (W)
V	wind velocity (m/s)
α	twist angle (in degrees)
β	overlap ratio (e/d)
ρ	density of air (kg/m^3)
1-2sc	single-stage two-bladed semicircular rotor
1-2tw	single-stage two-bladed twisted rotor
1-3sc	single-stage three-bladed semicircular rotor
1-3tw	single-stage three-bladed twisted rotor
2-2sc	two-stage two-bladed semicircular rotor
2-2tw	two-stage two-bladed twisted rotor
2-3sc	two-stage three-bladed semicircular rotor
2-3tw	two-stage three-bladed twisted rotor
3-2sc	three-stage two-bladed semicircular rotor
3-2tw	three-stage two-bladed twisted rotor
3-3sc	three-stage three-bladed semicircular rotor
3-3tw	three-stage three-bladed twisted rotor
2-3sc (wv)	two-stage three-bladed semicircular rotor with valves
2-3tw (wv)	two-stage three-bladed twisted rotor with valves

leading to their widespread use. The research proposal noted that small units could be manufactured for distributed generation of electricity in residential and commercial locations. The units would be grid connected to take advantage of net metering and would provide pollution-free generation of electricity using a renewable resource at a cost competitive with power supplied by the grid. The operation of Savonius wind turbine rotor is based on the difference of the drag of its semicircular vanes, depending on whether the wind is striking the convex or the concave part of the vane. The advantage of this type of rotor is that it is self-starting and relatively independent of the wind direction. It is simple to design and has relatively low construction cost. However, it has a low efficiency.

It is a known fact that accessories like end plates, shielding and guide vanes (flat, curved) usually increase the Savonius rotor performance; however, all of these increase the complexity of the rotor (Huda et al., 1992, Rajkumar, 2004). The rotor can develop a relatively high torque at low rotational speeds and is cheap to build, but it harnesses only a small fraction of the wind energy incident upon it. An attractive proposition for augmenting its harnessing effectiveness is to keep non-return valves placed inside the concave side of the blades. The valve opens automatically as a result of wind pressure when the blade advances towards the wind thereby experiencing lower flow-resistance. The centrifugal force automatically closes this valve during the power-harnessing part of the cycle. Valve-aided rotor is the mechanism to make direction independent and is the effective way of increasing power capability without unduly affecting the simplicity of rotor (Rajkumar and Saha, 2006). In addition to this, damages to turbine at higher velocities will be reduced with the valve mechanism.

2. Project objective

In recent times, a double-step or two-stage Savonius rotor has been investigated to find its feasibility for local production of electricity (Menet 2002, 2004). The challenge was to design,