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Adjacent wake effect of a vertical axis wind turbine

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Abstract

The main objective of this study is to understand the effect of turbine placement and surrounding structures. Using Urban Green Energy's UGE-4K vertical axis wind turbine and the ANSYS computational fluid dynamics package (CFX), a dynamic fluid analysis was undertaken looking at the wake of the turbine through a variety of different inlet speeds and rotational frequencies to determine suitable flow recovery for optimal placement of subsequent turbines. The results showed that the wake interference is minimal at around 5 times the diameter of the turbine downstream. Results also show that flow recovery was a lot slower to the right of the turbine especially along a line 15° from the centre of the turbine to the right as this is coincident with the vortices generated from the turbines rotation.

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Keywords: wake effect; vertical axis wind turbine; optimal turbine placement; CFD modelling.

1. Introduction

Harnessing the wind for power has been achieved by humans for over 5000 years with the Egyptians using sails to travel the Nile. The first windmills were discovered around the Persian-Afghan borders date back to 200 BC and the Dutch followed with their windmills for irrigation and drainage around 1300-1875 AD [1]. When the electrical generator was invented the application was soon used with the wind turbine and the first large wind turbine to

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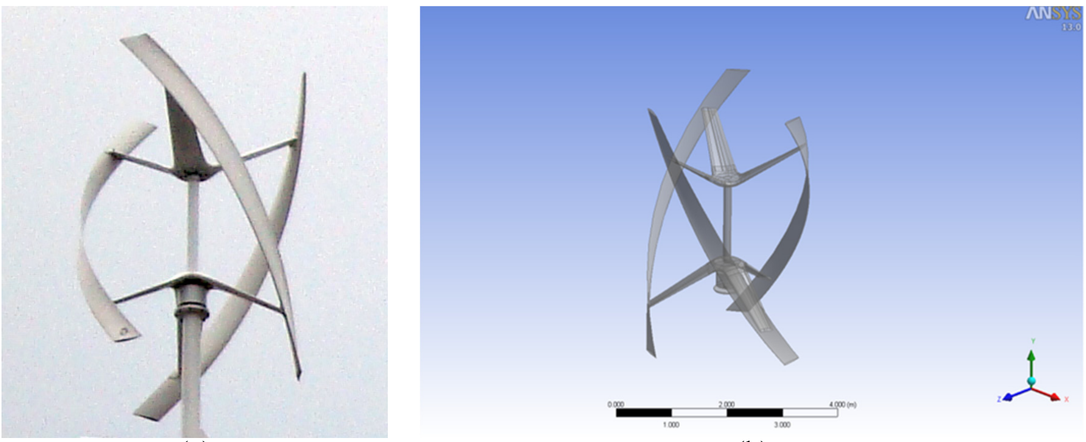
generate electricity was created in 1888 and was rated at 12 kW [2]. The progression continued with technology levels increasing and more research being undertaken it wasn't long till large scale wind farming was taking place with a notable case of California where over 16,000 machines ranging from 20-350 kW were installed between 1981 and 1990 for a total of 1.7 GW [3]. In recent years the global wind industry has been the fastest growing industry in electrical power generation with over 237,000 MW worth of capacity installed by the end of 2011.

The vertical axis wind turbine (VAWT) has been around for years but is starting to get more and more widely used as the world constantly increases its focus on renewable energy sources. The VAWT has the capability of providing a renewable energy source to the domestic, private and small commercial markets as it can be placed on rooftops and areas of turbulent flows with more success than a horizontal axis wind turbine (HAWT) [4-6]. The wind turbine power generation efficiency in commercial and domestic applications can significantly be affected by the built up geometry and the interference of adjacent turbines [7]. In order to maximize the power output, it is important to understand aerodynamic behavior of different building edges, surrounding structures and nearby installed turbine wakes. The wake of a turbine is an important part of analysis because it gives an assessment of the performance of the wind turbine, the other benefit of wake analysis is that an understanding of the downstream effect of the flow can be garnered and used for the optimizations of the placement of subsequent wind turbines for maximum effectiveness. Despite the importance, little information is available on optimal placement of turbines and their wake effect. Hence, the main objective of this study is to understand the effect of turbine placement and surrounding structures. Numerical and computational fluid dynamics (CFD) models were used to analyze wake and turbulence in the analysis of a commercially manufactured VAWT.

2. Methodology

2.1. Selection of wind turbine

Urban Green Energy (UGE) is a world leader in small wind and renewable energy systems, with installations across the globe. UGE designs, manufactures, and markets cutting-edge vertical axis wind turbines and hybrid renewable solutions with a track record of high performance, safety, and reliability. Fig. 1(a) shows the UGE-4K turbine marketed towards large domestic or moderate commercial scale. The turbine is designed to provide the maximum power possible from the wind over a given area. Detailed specifications of this wind turbine can be found in [8]. A simplified 3D CAD model of the UGE-4K turbine was developed for this study as shown in Fig. 1(b). The simplified CAD model of the turbine was used as the downstream wake profile is dependent on the whole physical geometry and rotational speed of the turbine rather than aerofoil type blade profile.



(a) (b)

Fig. 1. (a) UGE-4K turbine; (b) CAD model in ANSYS.