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Computational flow field analysis of a Vertical Axis Wind Turbine

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Abstract

The present work has used Computational Fluid Dynamics (CFD) to obtain the flow field characteristics of a novel Vertical Axis Wind Turbine (VAWT). The turbine used in this study features a multi blade design where both a stator and rotor blade array is used. The computational model is three-dimensional and contains full-scale turbine geometry measuring 2.0m in diameter and 1m in height. The pressure field across the wind turbine has been computed for operating conditions of $\lambda=0$ and $\lambda=0.4$ where it is shown to be non-uniform. The velocity field across the turbine has been obtained at $\lambda=0$ and $\lambda=0.4$ and has highlighted the presence of a jet flow passing through the central core of the turbine as it exits the rotor assembly. It is evident that under dynamic conditions and due to the direction of this jet flow a strong flow interaction occurs with the downstream rotor blades. This interaction results in rotor blades 5, 6 and 7 generating an opposing torque that acts against the direction of motion. Furthermore, it is noticed that rotor blades 10, 11, 12 and 1 contribute to the majority of overall rotor torque, which is a characteristic of this machines design.

Key words

Vertical axis wind turbine, CFD, flow field.

1. Introduction

Renewable energy technologies play a key role in the contribution to sustainable energy as a whole. Such technologies reduce our dependency on fossil fuel reserves and pave the way for long-term energy security.

Wind power has the potential to contribute significantly towards the sustainable energy sector over the coming years. This technology is seen to be the first renewable power generation technology (excluding large hydro projects) to become a genuine mainstream alternative for increasing the generation capacity across the globe **[1,2]**. Recent wind energy reviews have reported a rise of 22,000 MW in installed generation capacity in Europe between 2004 - 2007. This considerable increase has been the primary factor for global annual growth rates and recent studies state 60% of global installed capacity is now present in Europe alone **[3]**.

Over a period of 30 years, significant developments have been made in the wind engineering sector. Given the importance of this sector, a considerable amount of research has been carried out on the optimization of traditional turbine designs with a view to improving the energy capture/conversion efficiency. Further to this work, many research groups have proposed novel design configurations again with a view to generating high levels of power.

Upon reviewing the available literature, such machines are being designed without consideration to the installation site and wind conditions present. Many are of the view that if the UK is to continue increasing installed capacity, wind turbine manufacturers should look at installing machines in the urban environment. Due to the considerably lower cost of site, development along with the un-tapped residential market a turbine designed specifically for the urban environment should be investigated.

Given the low wind speeds present in this environment, start-ability is a primary concern. Solutions to this problem are in the form of high solidity multi-blade machines that generate high starting torques at both low wind and rotor speeds. The work of Takao et al **[4]** presents a novel radial cross flow wind turbine featuring five equally spaced NACA 0015 profile blades. Surrounding the blade inlet zone is a set of outer guide vanes, which are directed into the steam wise flow by a downstream tail vane. The turbine measures 0.6m in diameter and 0.7m in height with the machines performance output determined from wind tunnel tests. The authors report increases in power output of 1.5 times for the turbine with guide vane row.

Further investigations have been carried out into the effects of varying rotor solidity in which the number of blades is varied from 2-5. The turbine generates a power coefficient of 0.085 at a tip speed ratio of 0.95 for a five bladed rotor whereas reducing the number of blades results in a power coefficient of 0.15 at a tip speed ratio of 1.6. This highlights both the effect of solidity on peak power but also the speed up effects by reducing the number of blades.

Further novel designs have been documented in the form of utility scale vertical axis turbines. Park and Lee et al **[5,6]** have presented a radial cross flow multi blade VAWT that features a set of outer guide vanes again directed by a downstream tail vane. Here the outer guide vanes are placed upstream and are used to accelerate the flow into the rotor blade passages. A secondary side collector is used to funnel the flow into the passages on the leeward side of the machine, which would be otherwise un-used. Such modifications have allowed the authors to maximize power output and have reported