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ScienceDirect

Energy Procedia 110 (2017) 235 – 242

Energy Procedia

1st International Conference on Energy and Power, ICEP2016, 14-16 December 2016, RMIT University, Melbourne, Australia

Flow field and performance study of vertical axis Savonius type SST wind turbine

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Abstract

It has been suggested that waste heats or naturally available heat sources can be utilized to produce swirling flow by a design similar to that of split channels which is currently used to initiate fire whirls in laboratories. A new hybrid power system has been proposed combining the conventional Savonius wind turbine and split channel mechanisms. Previous computational and experimental works indicate a performance improvement in the new hybrid design (named as swirling Savonius turbine, SST) compared to the conventional Savonius turbine**.** However, the lack of detailed descriptions of the flow field around the swirling Savonius turbine inhibits complete understanding of performance of the hybrid power system. The aim of this study is to numerically explore the three-dimensional unsteady flow around the rotor, and develop a simulation method for predicting their aerodynamic performance using control volume based CFD package of ANSYS CFX. Sliding mesh feature of CFX allowed to solve the motion of the moving blades. Numerical simulations results of SST were compared with the experimental results. A discussion on the detailed flow field characteristics, including velocity vector, velocity streamlines, pressure distribution, vorticity analysis, and examination of power and torque coefficients behavior are presented.

Peer-review under responsibility of the organizing committee of the 1st International Conference on Energy and Power.

Keywords: Wind energy; Savonius wind turbine; Split channel; Swirling flow; Power coefficient; CFD.

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Peer-review under responsibility of the organizing committee of the 1st International Conference on Energy and Power.
doi:10.1016/j.egypro.2017.03.133

1. Introduction

Wind power has now firmly established itself as the mainstream electrical generation option with the least cost when adding new capacity to the grid, and the price continues to fall [1]. Greenpeace predicted that wind power could reach nearly 2000 GW by 2030 supplying 16.7% to 18.8% of global electricity, helping save over 3 billion tons of CO_2 emissions annually [1]. Solar energy, on the other hand, covers a minor portion of global energy demands and generates less than 1% of the total electricity supply [2]. This is due to solar power being considered the most expensive type of renewable energy, although renewable sources may serve the best solution for decentralized energy supply for remote communities [3, 4]. However, the main challenge for stand-alone applications in remote regions is that the renewable energy sources are dependent on unpredictable factors such as weather and climatic conditions and may not match the load demand. The complementary nature of solar and wind energy can overcome the weaknesses of one through the strengths of the other. The hybrid renewable power generation with energy storage device may render the renewable energy sources more reliable and affordable means of generating electricity.

Among the wind turbines, Savonius wind turbine has many advantages over others such as simplicity in construction, self-starting and operating capability at low wind speed, and better visibility to animals, and free from harmful low frequency noise [5]. The Savonius turbines are popular for ventilation and pumping applications, but not employed for large scale power production projects because of low power coefficient (17% maximum) and slow running behavior [6]. Improving the power coefficient of the Savonius turbine can pave the way for using it for the local generation of electricity in rural environments where power is crucial for human development.

An innovative technique of performance improvement was proposed by combining the split channel mechanism with the primary Savonius wind turbine mechanism to a new hybrid design of Swirling Savonius turbine (SST) [7]. They proposed the hot air sourced from either solar thermal system or industrial waste heat as the heat source for the split channel. Split channels are capable of inducing swirling flow using hot air plume at the bottom of the channel [8]. An increase in rotational speed and power coefficient of the SST compared to conventional Savonius turbine was reported [7]. Experimentally investigation on the geometrical parameters of the SST rotor confirmed a 24.12% increase in power coefficient compared to the optimum conventional Savonius turbine [5]. The SST rotor consists of two identical blades which are moved sideways and overlap like the conventional Savonius turbine as shown in Fig. 1. Unlike the conventional rotor of 180º blade arc angle, the inner tips of the blades extend further to construct the split channel which accommodate inside the turbine geometry [5]. A bottom hole acts as the hot air inlet of the swirling chamber, whereas, the top end plate provides an opening to the chamber.

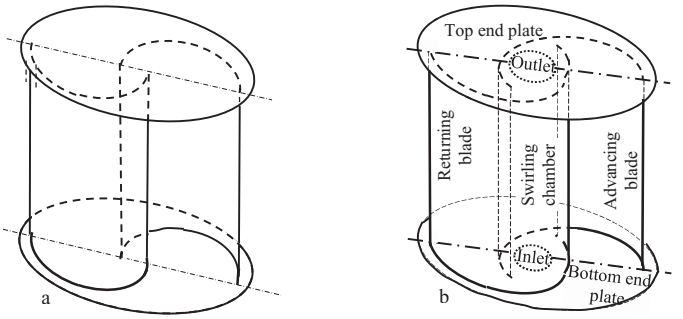

Fig. 1. Schematic diagrams of (a) conventional and (b) Swirling Savonius turbines

The lack of detailed descriptions of the flow field around the SST prevents complete understanding of working behavior of the turbine. To understand the combined mechanism of the hybrid rotor, a discussion on the detailed flow field characteristics, including the velocity vectors, velocity streamlines, pressure and temperature distributions, and vorticity analysis in the swirling chamber are required. In the present study, a computational fluid dynamics (CFD) model is developed using the finite volume based package of ANSYS-CFX 14.5 to explore the 3D unsteady flow pattern around the rotor, to understand the torque generation mechanism, and to analyze the performance of the hybrid turbine.