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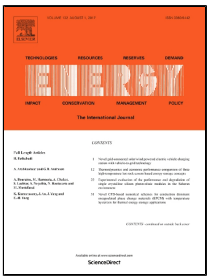

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Numerical study of energy recovery from the wakes of moving vehicles on highways by using a vertical axis wind turbine

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Abstract The wind energy restored in the wakes of high-speed moving vehicles on highways has considerable potential but has yet to be used. In this study, a vertical axis wind turbine (VAWT) is used to recover energy from the wake of vehicles on highways. The VAWT is designed to be placed on the medians of the highway and produce power from the wakes of vehicles on both sides. To evaluate the performance of the VAWT and to determine the mechanism of interactions between the moving vehicle and the turbine, three-dimensional computational fluid dynamics simulations based on the Reynolds-Averaged Navier–Stokes equations are performed. Five typical situations, including one car on the passing lane, one bus on the passing lane, two opposite moving cars on the passing lane, one car on the fast main lane, and one bus on the fast main lane, are considered and studied. Results show that the VAWT could generate power from the wakes of vehicles on the passing lane. The maximum average power coefficient is 0.00464, which corresponds to an average power of 139.60 W.

Key words: wind energy; wind turbine; VAWT; highway; CFD; energy recovery

1. Introduction

In recent years, the problems of fossil resources and worldwide climate are becoming increasingly serious because of the rapid development of the industrial economy and the fast growth of the world population. Most countries, especially developing countries such as China, face the contradiction between the increasing demand and the limited supply of fossil resources. Thus, the use of renewable energy, such as wind energy, solar energy, and hydrokinetic energy, to generate electricity has gained worldwide interest in the past decade. The Chinese government has consistently treated highway construction as an important means to stimulate economic growth and has built a nationwide network of highways. By the end of 2015, the highway network of China reached 123,500 km [1], and this number is expected to increase continuously. On the basis of the dynamic monitoring data of highways in 23 Chinese provinces, the total highway traffic flow was 516 million in July 2016 [2]. High-speed vehicles moving on highways produce strong disturbances to the air and transmit energy to their wakes in the form of localized wind energy [3]. The potential of highway wind energy is high, considering the large mileage and the high traffic flow. The small-scale utilization of this type of energy may produce sufficient electricity to power sensor systems or streetlights. Meanwhile, in large-scale applications, the recovered electricity may be connected to the grids.

The idea of recovering energy from the wakes of vehicles has been previously proposed [4-8]. In these studies, vertical axis wind turbines (VAWTs) were used instead of horizontal axis wind turbines. The wind directions on both sides of the rotor are opposite because of the opposite motion of vehicles, and the opposite aerodynamic forces could drive the rotor [4]. Taskin et al. [5] designed a combined solar and wind system to be planted in the median of the highway; the system uses a multi-stage Savonius rotor to generate power from the wind produced by cars. Krishnaprasanth et al. [4] designed a maglev turbine for highway wind power generation. However, the above two studies remain in the design process; a theoretical, numerical, or experimental analysis of their designs has yet to be conducted. Furthermore, in the prototype stage, a Savonius turbine [6] and a hybrid wind turbine composed of a Darrieus rotor and a Savonius rotor [7, 8] were designed and tested. These prototype studies showed the feasibility of using wind turbines to generate power from the wakes of moving vehicles. However, these tests are overly simple; no computational or field measurements were performed to show the viability of these approaches, and the