Study on Characteristics of Darrieus-type Straight-bladed Vertical Axis Wind Turbine by Use of Ailerons

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ABSTRACT

Darrieus type wind turbine has high turbine efficiency and small starting torque, so it is requiring strong wind speed to start rotating. This paper presents new starting assist method of Darrieus turbine using movable aileron. To confirm an effect of the aileron, the paper conducted wind tunnel experimental tests about characteristics of starting torque, starting wind speed and load torque. Tested turbine is four-blade and the ailerons tested were a fixed-angle aileron and three configurations of movable ailerons. The movable ailerons are increased starting torque, and the wind speed for start-up is reduced. When using a movable aileron the load torque at low rotational speed region is increased. Furthermore, the load torque of the turbine with AR-type movable aileron is roughly equal to the turbine of bare blade (without aileron) at high rotational speed region.

KEY WORDS: wind power generation; Darrieus-type straight-bladed VAWT; starting torque; load torque; movable aileron.

INTRODUCTION

Horizontal-axis wind turbines (HAWTs) have come into wide use for electric power generation, as they can be greatly scaled up in size. Where the wind is susceptible to irregular variations in direction, however, there have been some successful installations of Darrieus wind turbines (WTs), one class of vertical-axis wind turbines (VAWTs), which are unaffected by changes in wind direction. Darrieus WTs are classified as lift-type WTs and, therefore, have considerable advantages over drag-type WTs, but have difficulties in self-starting. When they are specifically designed to be self-starting, no separate self-starting device is needed, but when they are designed for maximize efficiency, a starting device is generally necessary. The electric generator is itself often used for starting (Takami, Nakahara, Takahara, Shimizu, Taketoh, Ichikawa, Sekiya and Sakai, 1984); another approach is to control the pitch angle of the blades of a giromill, which is a straight-bladed VAWT (Lazauskas and Kirke, 1992). Another example that has been proposed is a hybrid composed of a fixed-pitch giromill, without a pitching mechanism, mechanically combined with a drag-type Savonius rotor (Okamoto, Ushiyama, Hagiwara and Makino, 1994). However, these approaches have some issues, such as follows. If the generator is used for starting, power must be available to be supplied to the generator; the pitch control mechanism of the giromill necessitates a more complex structure of the WT; and if a Savonius rotor is built directly into the axis of the WT, it reduces the output of the WT in comparison to an unmodified Darrieus turbine in the high-rpm range, where the efficiency is the highest (Okamoto, Ushiyama, Hagiwara and Makino, 1994).

It has been proposed to add ailerons to the blades of a straight-bladed VAWT in the form of spoilers (Hashidate and Baba, 1994), but the purpose of these was to increase drag in order to slow the WT under high winds. In this study, it is proposed to add ailerons to the blades of a straight-bladed VAWT in order to improve self-starting. The blades used here are cambered with the camber line on a circular arc. These blades have been employed in a tidal current power generation system, in which the fluid has a far different density (Shiono, Naoi and Suzuki, 2007), and were found to provide more efficiency than symmetrical blades in water channel tests (Kihoh and Shiono, 1992).

In order to investigate how the WT characteristics were changed by the ailerons, initially, the ailerons were mounted at a fixed angle (fixed-aileron blades), and this arrangement was observed for the effect of the ailerons on WT starting torque. The fixed-aileron blade experiment showed that the torque is increased in some parts of the blade orbit and decreased in others, and the mean starting torque is not greatly increased. We propose movable ailerons positioned by a mechanism that extends them only in locations where they increase the starting torque. We show in a wind tunnel experiment that movable ailerons increase the starting torque of the WT and that the wind speed needed for starting (start-up) is decreased.

Self-starting is not the only important feature of a WT; the load characteristics are just as important. Therefore, the influence of the movable ailerons on load characteristics is also examined. Due to the effects of the fittings for controlling the angle of the movable aileron in the model constructed here, it was noted that at high rotational speed the ailerons reduce the WT output below the power obtained in a model whose blades have no ailerons (bare blades), so a method is demonstrated for overcoming this.

STARTING CHARACTERISTICS WITH FIXED-AILERON BLADES

Figure 1(a) shows the straight-bladed VAWT used in this experiment.