Proceedings of the 9th World Congress on Momentum, Heat and Mass Transfer (MHMT'23)
London, United kingdom – April 11 – 13, 2024
Paper No. ENFHT 274
DOI: 10.11159/enfht24.274

Vertical Axis Wind Turbine Adapted For Installation on Pitched Roof with Photovoltaic Panels and Effects on Heat Transfer

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Extended Abstract

The vertical axis wind turbines (VAWT) can be generally divided into Darrieus-type and Savonius-type. The Darrieus-type have higher power coefficient but also operate at a higher tip speed ratio (TSR), while the Savonius-type usually have a lower power coefficient at lower TSRs. VAWTs are usually considered as a good option for urban environments due to their ability to operate in environment with changing wind direction without additional mechanisms. One on the most considered installation locations are the roof tops. In [1], it was shown that a V-shaped roof guide can significantly increase the power coefficient of a low-TSR Darrieus-type VAWT. This was shown at a low tip speed ratios (TSR<1) and the increase of the power coefficient (c_P) was from 5% to 10%. As the Savonius-type VAWT is usually more appropriate for low TSR operation, the objective of the current paper is to investigate the possibilities implementing the Savonius-type turbine for several different pitched roof installations. As these installations are also usually a part of a photovoltaic (PV) panel system, we also investigate the possible effects on the heat convection and potential advantages related to increasing the PV system efficiency.

The classical Savonius-type wind turbines (SWT) has semi-circular blades which can obtain power coefficient up to 25% [2]. In modern research of SWT, the objective was mostly related to increasing the SWT efficiency (i.e. power coefficient). For example, Bach and Benes in [3]–[5] investigated blade shapes composed of an inner straight part and an outer blade part forming a circular-arc which spans less than 180°. The efficiency in this research has shown increased to 28%. Many recent studies motivated by the same problem tried to further increase the efficiency using composite and complex geometrical shapes (elliptical [6], multiple smaller quarter [7], spline [8]) with no major improvement. A more promising improvement was numerically shown to increase the efficiency to 37% using 2D CFD [9], or 34% with 3D CFD [10]. This novel shape was named the scooplet-based SWT. It was also experimentally shown that the novel optimized geometry improves the efficiency [11]. In the experiments, the improvement was investigated at low Reynolds number, however a 37% improvement over the classical SWT was achieved. Thus, the current paper investigates more practical applications of the scooplet-based SWT, related to different pitched roof installations.

The tests were conducted numerically using 3D CFD considering only a single wind direction. The first test investigates the appropriate location of the SWT on the pitched roof and the appropriate rotation direction. It was shown that with optimized positioning, the pitched roof can lead to a 14% increase of the power coefficient compared to turbine a stand-alone version. This is however for a single wind-direction, it is expected that different wind directions will negatively impact the turbine efficiency (due to reduced relative wind speed since the wind angle would not be perpendicular to SWT axis). Addition of a V-shaped roof guide as in [1], leads to local wind speed increase which significantly increases the SWT efficiency (up to 70% which was also the case in [1]). The turbulence generated by the turbine wake also increases the heat conduction of the PV system, which can act as a passive cooling mechanism.

This work was supported by the Croatian Science Foundation [Grant Number IP-2022-10-8856].

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