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# Evaluation of a Savonius Wind Turbine in the Vicinity of a Circular Cross-sectional Building

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**ABSTRACT:** Today's big cities are full of tall buildings requiring a lot of energy. On the other hand, dispersed electricity generation is an integral part of these cities in developed countries. To use small-scale wind turbines and dispersed electricity generation, the performance of such turbines in the vicinity of various buildings in the urban environment should be investigated. In this study, the power characteristics of a conventional Savonius wind turbine in the vicinity of a large circular cross-sectional building are assessed under a free-wind speed of 6 m/s. To this, the Savonius rotors are installed at a constant non-dimensional distance of 2 from the building envelope at different installation angles of 30°, 45°, 60°, and 90°. Additionally, to understand the effects of the rotation direction of the rotor, two possible rotations, namely, inward and outward rotations are studied. Computations are performed for tip speed ratios of 0.4, 0.8, and 1.2. The obtained results reveal the significant impacts of installation angle and rotation scenario. Examination of the obtained data shows that, depending on the for tip speed ratio, with inward rotation of the rotor at installation angles of 60° and 90°, the maximum improvements in the power coefficient are found compared to the reference case.

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## 1- Introduction

The lack of fossil resources and environmental pollution have made developed countries look for clean energy sources. Wind energy is one of these sources, whose energy can be used by using wind turbines. There are different types of wind turbines, of which the Savonius vertical axis turbine is one of them. Improving the performance of Savonius wind turbines by changing the blade profile has been the subject of many researches [1-5] in the past.

Due to the frequent collision of wind with buildings in urban areas, its flow is often unstable and chaotic. The operation of wind turbines in these areas requires more research and study. Abohela et al. [6] compared six types of roofs with different shapes for a building with the aim of finding the best roof profile for wind turbine installation. For all investigated roofs, it was observed that the region of maximum turbulence intensity extends directly from the top of the roof to a distance of 1.3 times the height of the building. Some previous studies have also addressed the performance of small-scale wind turbines in the vicinity of buildings. For example, the turbulence characteristics and efficiency of a two-blade Darius wind turbine between two tall buildings side by side was a study conducted by Sepehrianazar et al. [7]. By examining the results obtained for the dimensionless gap spaces of 1.5 and 3, 75% and 45% enhancements in local wind speed were observed between the two buildings, respectively.

In the comprehensive review of technical literature, it can be seen that the present study is innovative in many ways. In this field, the number of studies conducted is very limited. In this research, the performance of the conventional Savonius turbine around a high-rise building with a circular cross-section is studied and parameters such as the direction of rotation, inward and outward, the installation angle of 30, 45, 60, and 90 degrees, and the tip speed ratio 0.4, 0.8 and 1.2 have been carefully examined, which has not been seen in previous researches.

## 2- Geometry and details of numerical method for the reference case

In this research, with the help of CFD, the performance of the conventional Savonius wind turbine in the vicinity of a building with a circular cross-section is investigated two-dimensionally. A fixed non-dimensional distance (S/D) of 2 is considered for placing the turbine around the building. All calculations have been done for the free-wind speed of 6 m/s. To compare the performance of the conventional Savonius wind turbine in the vicinity of the high-rise building with the reference case (wind turbine installed in the free flow of wind without the presence of the building), the reference case has

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**Table 1. Validation of the numerical code for conventional Savonius wind turbine in the absence of the building**

| Authors | Re | Cp | | |
|---|---|---|---|---|
| | | TSR | | |
| | | 0.4 | 0.6 | 0.8 |
| Roy & Saha. [8] | $8.63\times10^4$ | 0.191 | 0.248 | 0.239 |
| Tahani et al. [9] | $8.63\times10^4$ | 0.169 | 0.218 | 0.244 |
| Hassanzadeh and Mohammadnejad [4] | $8.63\times10^4$ | 0.171 | 0.220 | 0.238 |
| Asadi and Hassanzadeh [10] | $8.63\times10^4$ | 0.172 | 0.222 | 0.240 |
| Present study | $8.63\times10^4$ | 0.160 | 0.207 | 0.244 |

been investigated first. To perform this simulation, a two-dimensional rectangular computing domain is defined with dimensions of 14D and 6D in the flow direction and vertical direction, respectively, where D is the diameter of the rotor.

Continuity and time-averaged momentum equations governing the incompressible flow are as follows [3]:

$$\frac{\partial \bar{u}_i}{\partial x_i}=0 \tag{1}$$

$$\frac{\partial \bar{u}_i}{\partial t}+\frac{\partial}{\partial x_j}(\overline{u_i u_j})=-\frac{1}{\rho}\frac{\partial \bar{p}}{\partial x_i}+\frac{\partial}{\partial x_j}(\upsilon\frac{\partial \bar{u}_i}{\partial x_j}-\overline{u_i' u_j'}) \tag{2}$$

In equation (2), the last term represents the Reynolds stresses simulated by the SST k-ω method.

After the grid size is independent for the reference case, to validate the applied numerical code, the results obtained for the mean power coefficient are compared with the data available in the open literature for different values of the tip speed ratio in Table 1.

## 3- Simulation of the flow around the building with a circular section

Basically, the flow around a building with a circular cross-section is geometrically very similar to the flow around a cylinder. Therefore, the data related to the flow around the cylinder has been used for validation. For this simulation, a rectangular computational domain with dimensions of $27D_B$ in the flow direction and $14D_B$ in the vertical direction has been used, where $D_B$ is the diameter of the building.

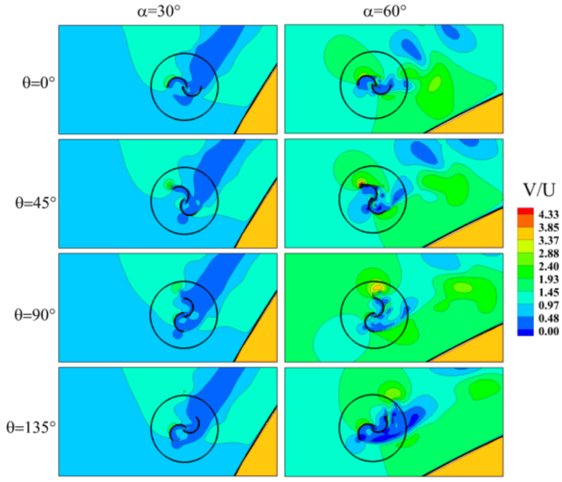


**Fig. 1. The effect of the Savonius rotor installation angle in the vicinity of the building on the velocity field for inward rotation and tip speed ratio of 0.8**

## 4- Results and discussion

### 4- 1- The effect of the rotor installation angle in the vicinity of the building

Figure 1 compares the normalized velocity fields for two installation angles of 30° and 60° for inward rotation and tip speed ratio of 0.8 at different azimuth angles. It is clear that in all azimuth angles, the velocity field at the installation angle of 60° is significantly stronger than that of 30°. The presence of a stronger velocity field around the rotor at an angle of 60° causes the flow with higher kinetic energy to be injected into the concave part of the advancing blade (increase in positive torque) and the convex part of the returning blade (decrease in negative torque) and thus increase the torque produced by the rotor.

### 4- 2- Mean power coefficient

Figure 2 shows the changes of the mean power coefficient with the tip speed ratio in all installation angles and two directions of rotation, namely, inward and outward. By examining the obtained results, it can be seen that the minimum mean power coefficient belongs to the installation angle of 30° regardless of the direction of rotation of the rotor and the tip speed ratio. On the other hand, the highest mean power coefficient belonging to the inward rotation mode is obtained at installation angles of 60° and 90° depending on the tip speed ratio.

## 5- Conclusions

In all installation angles except 30°, inward rotation compared to outward rotation led to more improvement in the power characteristics of the rotor. Due to the existence of lower wind potential, it is not logical to install the Savonius turbine in the vicinity of the desired building at an angle of 30°. On the other hand, depending on the value of the tip speed ratio, the installation angles of 60° and 90° in the inward rotation mode have the highest performance, which

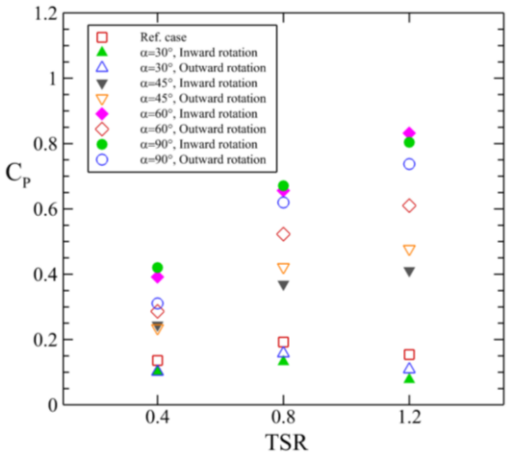


**Fig. 2. Variations of the mean power coefficient of the wind turbine in the vicinity of the building with tip speed ratio for all installation angles and inward and outward rotations**

are recommended for the installation of the conventional Savonius wind turbine in the vicinity of the desired building.

## References

[1] C.M. Chan, H.L. Bai, D.Q. He, Blade shape optimization of the Savonius wind turbine using a genetic algorithm, Applied energy, 213 (2018) 148-157.

[2] S. Roy, A. Ducoin, Unsteady analysis on the instantaneous forces and moment arms acting on a novel Savonius-style wind turbine, Energy Conversion and Management, 121 (2016) 281-296.

[3] R. Hassanzadeh, M. Mohammadnejad, S. Mostafavi, Comparison of various blade profiles in a two-blade conventional Savonius wind turbine, Journal of Energy Resources Technology, 143(2) (2021) 021301.

[4] R. Hassanzadeh, M. Mohammadnejad, Effects of inward and outward overlap ratios on the two blade Savonius type of vertical axis wind turbine performance, International Journal of Green Energy, 16(15) (2019) 1485-1496.

[5] N. Alom, U.K. Saha, Influence of blade profiles on Savonius rotor performance: Numerical simulation and experimental validation, Energy Conversion and Management, 186 (2019) 267-77.

[6] I. Abohela, N. Hamza, S. Dudek, Effect of roof shape, wind direction, building height and urban configuration on the energy yield and positioning of roof mounted wind turbines, Renewable Energy, 50 (2013) 1106-1118.

[7] F. Sepehrianazar, R. Hassanzadeh, I. Mirzaee, Turbulence and Energy Assessment of a Two Bladed H-Type Vertical Axis Wind Turbine Between Two High-Rise Buildings, International Journal of Heat and Technology, 37(4) (2019) 948-957.

[8] S. Roy, U.K. Saha, Wind tunnel experiments of a newly developed two-bladed Savonius-style wind turbine, Applied Energy, 137 (2015)117–125.

[9] M. Tahani, A. Rabbani, A. Kasaeian, M. Mehrpooya, M. Mirhosseini, Design and numerical investigation of Savonius wind turbine with discharge flow directing capability, Energy, 130 (2017) 327-338.

[10] M. Asadi, R. Hassanzadeh, Effects of internal rotor parameters on the performance of a two bladed Darrieus-two bladed Savonius hybrid wind turbine. Energy Conversion and Management 238 (2021) 114109.

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