Performance Analysis of a New Vertical Axis Turbine Design for Household Usage

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ABSTRACT

The popularity of small wind turbines intended for domestic use has significantly increased during the recent years, and it is reasonable to assume that this trend will continue given the present political and economic environment. There is a greater need for clean, pollution-free energy due to worries about climate change. In this study, a 1.5 KW vertical-axis Darrieus helix wind turbine for residential use was designed and its performance was mathematically evaluated under typical wind speed circumstances of 12 m/s. The study is split into two sections: In the first, we examined a standard wind turbine design with three identical blades, whereas in the second, the blades were different, each with a unique airfoil with a varying chord, even though they shared the same rotor diameter. For each case, 5 CFD simulations were performed in order to determine the power characteristics of the wind turbines. To correctly set up the computational domain, the number of elements and the minimum element size were taken into account whereas mesh dependency analysis was performed. In order to compare the results, the vorticity magnitude was measured at 4 different blade locations in each boundary condition. The results showed that when the power coefficient of the turbines is considered, such geometry adjustments are possible. Furthermore, the evolution of the torque coefficient over a full 360-degree rotation was studied. A summary of the improvements in performance resulting from the geometry adjustment is provided.

Keywords-vertical-axis wind turbine; Darrieus; CFD; power coefficient

I. INTRODUCTION

The world's energy systems are radically changing to focus on environmentally friendly and sustainable options [1]. At the same time wind power is becoming a key component in this search for renewable energy. In the current context of energy crisis [2] and of a potential future crisis [3], European Union regulations on nullifying combustion gas emissions by the year 2050 make the development of alternative energy sources like wind turbines or solar power plants [4], one of the only viable options to sustain a society that depends on electricity [5]. Energy availability over the past 30 years [6] shows how difficult and slow it is to eliminate natural gas, solid fossil fuels, and petroleum product exploitation as energy sources. While renewable energy sources have steadily increased in quantity, burning-dependent energy sources have declined at a much slower pace. The current longevity of wind turbines has only served to further slow down this process—after a mean service life of about 20 years, the blades need to be replaced, whereas the old parts are either recycled, burned, or end up in landfills. This raises a number of environmental concerns about these energy sources effects [7].

Wind energy, a promising and eco-friendly resource, has shown remarkable growth over the past few decades [8]. Notable examples that have made substantial contributions to wind energy expansion include countries such as Romania [9], Switzerland [10], or China [11, 12]. Furthermore, the European Union as a whole has experienced significant advancements in wind energy utilization [13, 14]. Due to their advantages over the Horizontal Axis Wind Turbines (HAWTs) [15], in urban and suburban locations [16], Vertical Axis Wind Turbines

(VAWTs) have become a feasible alternative among all wind turbine configurations for home usage. Owing to their omnidirectional operation, smaller and more space-efficient design, and quieter operation [17, 18] than those of an HAWT, the VAWTs are more suitable for domestic use. Wind turbines categorization does not solely take axis orientation into account. Wind turbines can be categorized by how the turbines interact with the electrical grid (off-grid or on-grid) and how they harvest the wind kinetic energy (with the help of the drag force or the lift force). However, the same mathematical formula [19] - which states that wind power is exactly proportional to speed to the third power - is used to begin the design process in all cases.

A wind turbine's operating environment [20], including its intended power output, average wind speed in the region, placement height, and terrain, must be taken under consideration during the designing process. It is essential to analyze the average wind speed [21] in the area. This analysis is important in determining the turbine primary dimensions (height and diameter) as well as the number of blades the turbine should use. Odd numbers of blades are advised since even numbers significantly reduce the tip speed ratio interval across which the turbine can produce power [22]. The latter also increase the possibility of aerodynamic equilibrium [23], which might leave the turbine ineffective in the starting process. Geometry adaptation is an essential way to improve VAWT performance. Researchers are investigating ways to optimize turbine height, support structures, blade positioning [24], blade shape [25], number of blades [26], and the number of rotors through iterative design modifications and Computational Fluid Dynamics (CFD) - based analysis. Authors in [27] examine a new VAWT with two counter-rotating rotors. Furthermore, in order to achieve greater efficiency and lower cut-in speeds, variables like material choice, blade curvature, and aerodynamic characteristics are crucial. As a result, VAWTs are more suited for low-wind speed areas frequently encountered in urban environments [28].

The simulation of CFD models use has become an indispensable method in contemporary wind turbine design when it comes to maximizing the power coefficient and the overall efficiency while trying to minimize the cost. The complex fluid flow phenomena surrounding VAWTs, which are governed by the Navier-Stokes equations [29], may be thoroughly examined using CFD models. Genetic algorithms [30] are a class of optimization algorithms that may be used to optimize the VAWT design [31]. They are inspired by the principles of genetics and natural selection. The initial population of possible VAWT designs is randomly generated at the first stage, and each design is represented by a set of parameters [32]. Subsequently, an assessment function will be employed to assess the effectiveness of every design. Afterwards, the genetic processes of selection, crossover, and mutation are implemented, and a fitness function is utilized to measure the performance of each design. Following that, the population evolves over a number of generations [33]. The best design of the final population is chosen when the algorithm stops, either by obtaining an optimum design or when a stop condition such as the maximum generations number is reached [34].

This research proposes a novel, asymmetric profile consisting of 3 distinct NACA airfoils with varied chord lengths positioned on the same radius. This new design intends to enhance the VAWT's overall performance and aerodynamic efficiency, especially in low-wind speed areas that are common in urban environments. The suggested adaptation of the geometry has the potential to improve energy extraction while preserving the small size and space-saving design of VAWTs.

II. GEOMETRY GENERATION

This study examined two geometric cases: the first has 3 identical NACA airfoils with the same chord length that are symmetrically positioned with respect to the turbine vertical axis of symmetry. The second involves 3 distinct NACA airfoils with varying chord lengths. Five simulations were run for each example in order to determine the relationship between the power coefficient and the Tip Speed Ratio (TSR). A 3D CAD model of the VAWTs under consideration is displayed in Figure 2, along with a cross-section for each case.

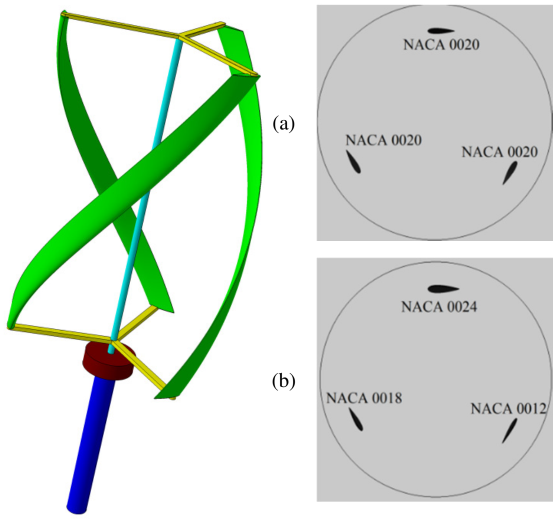

Fig. 1. The Darrieus VAWT: (a) baseline, (b) new solution.

The parameters of both geometries taken into consideration are listed in Table I. The final value taken into account in the final results is the chord's second value. In order to enhance the performance of blades 1 and 3, which were determined to have a lower power coefficient than the second blade following a CFD simulation at the ideal TSR, the chord was increased.

TABLE I. GEOMETRY PARAMETERS

Parameter	Value	
	Baseline case	**New case**
Blade 1 airfoil	NACA0020	NACA0012
Blade 2 airfoil		NACA0018
Blade 3 airfoil		NACA0024
Blade 1 chord	0.3 m	0.33 m
Blade 2 chord		0.3 m
Blade 3 chord		0.356 m
Blade diameter	2 m	2 m
Blade height	3 m	3 m
Wind speed	12 m/s	12 m/s

III. NUMERICAL SIMULATION

A three-dimensional simulation is perhaps the most accurate way to simulate the flow around a wind turbine. This research focuses on the airflow in a two-dimensional sector of the turbine, since the primary drawback of the 3-D simulation is the computational work and time required to complete the simulation. Nevertheless, this will not allow the consideration of the impact of the vortices that may be formed at the top or the bottom of each blade. The two-dimensional geometries under analysis were created using the Ansys Design Modeler and were then simulated with the Ansys Fluent. An interface was formed between the rotor and stator regions of the partitioned spatial domain. For mesh dependency analysis, three distinct meshes were created for the basis geometry, as indicated in Table II. The dimensions of the considered domain used in the CFD simulations are displayed in Figure 2.

TABLE II. BASELINE GEOMETRY MESHES

Mesh number	Type	Number of elements
1	Coarse	~150,000
2	Medium	~200,000
3	Fine	~250,000

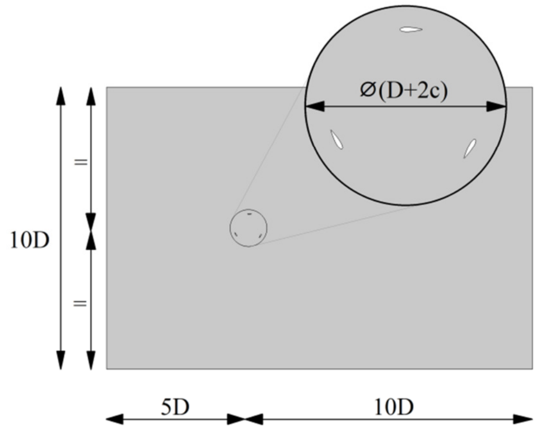

Fig. 2. Dimensions of the domain: stator region with zoom on the rotor region, where *D* is the turbine diameter and *c* is the baseline blade chord.

The disposition of the fine mesh elements can be observed in Figure 3. The boundary conditions for each simulation were defined as indicated in Figure 4. The intake condition specifies the air inlet velocity, which is 12 m/s. The interface defines the connection between the rotor and the stator and allows the air to flow from one region to the other. The flow region area is defined internally. The exit pressure of the air is defined as 101325 Pa, the standard pressure at mean sea level. Symmetry is set between the two borders of the stator region (the highest and lowest frontiers), and Wall denotes the portion of the blades (the airfoil) that prevents air flow.

The SST k-ω model, which solves a set of two partial derivative differential equations for the turbulence kinetic energy (k) and the particular dissipation rate (ω) for each element on the mesh, is the turbulence model utilized in this study

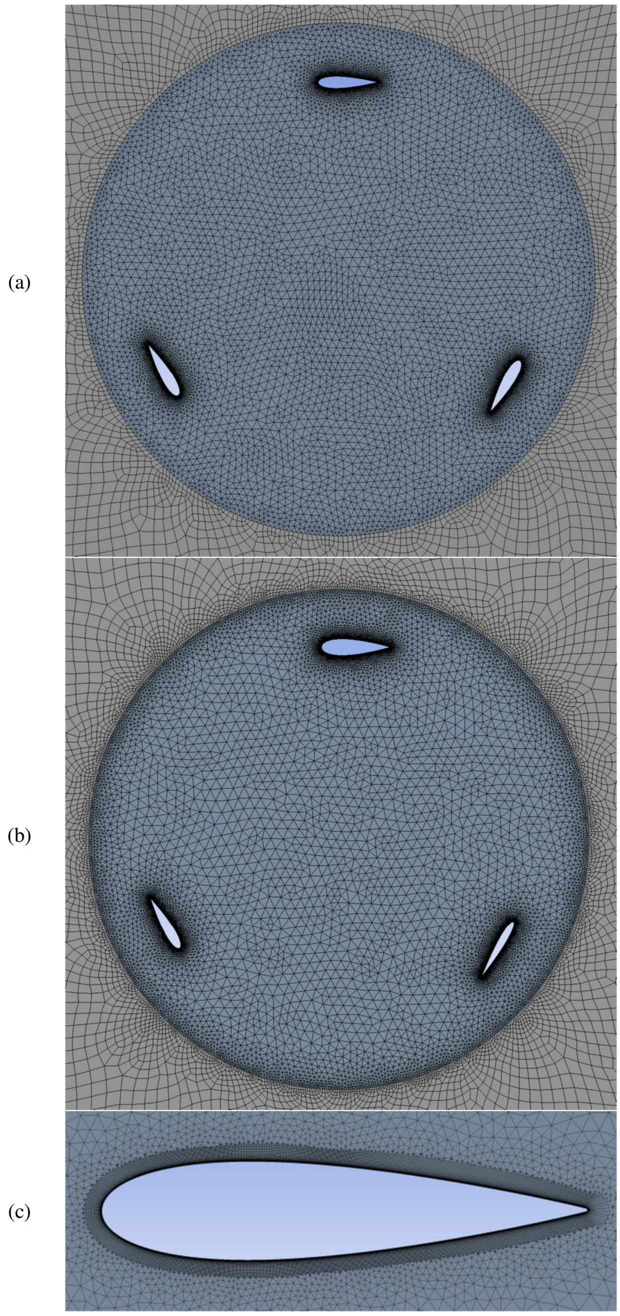

Fig. 3. Mesh: (a) baseline, (b) new solution, (c) zoom on the blade's inflation.

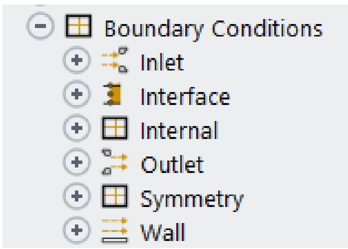

Fig. 4. Boundary conditions in Ansys Fluent.

Five case studies were explored for each mesh type, each corresponding to a different TSR value between 1 and 3. The relation between the TSR and the rotational velocity (ω) is:

$$TSR = \frac{\omega D}{2V} \quad (1)$$

where V represents the wind speed and D is the turbine diameter. The rotational velocity and time step size, which represent one degree of angular movement during every iteration, are computed for every case by (1).

The primary goal of the CFD simulations is to capture the fluctuation in the torque coefficient with the turbine's azimuth angle (θ) throughout 10 complete rotor revolutions. This information is then used to compute the mean value of the torque coefficient during the last rotation:

$$\overline{C_m} = \frac{\sum_{i=1}^{360} C_{m,i}\Delta t}{\sum_{i=1}^{360} \Delta t} \quad (2)$$

Equation (3) is used to calculate the power coefficient (C_p) of the wind turbine based on the mean value of its torque coefficient:

$$C_p = TSR \cdot \overline{C_m} \quad (3)$$

IV. RESULTS

Following the simulations completion, the torque coefficient (C_m) in the first scenario could be shown to repeat itself during a full rotation. At 120 degrees of azimuth angle θ the variation's maxima and minima are equally spaced, suggesting that the geometry is made up of 3 identical blades. After the mesh dependency study, where nominal TSR value was used, we conducted the remaining simulation with the medium mesh size. The torque coefficient quantifies the effectiveness of a wind turbine in converting wind energy's kinetic energy into mechanical torque, which can subsequently produce electricity. The ratio between the actual mechanical torque generated by the wind turbine rotor and the greatest theoretical torque that might be generated with the same wind speed and rotor area is known as the torque coefficient. Figure 6 illustrates the variation of the torque coefficient of each blade.

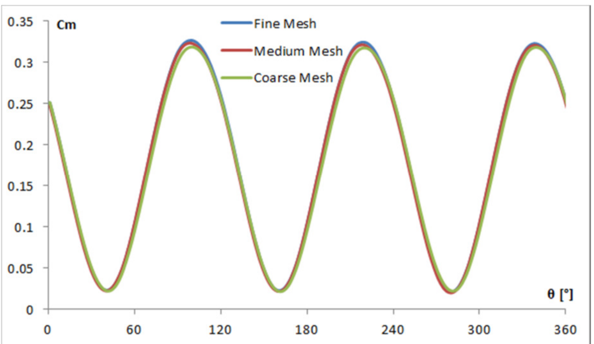

Fig. 5. Torque coefficient variation for mesh dependency.

(a)

(b)

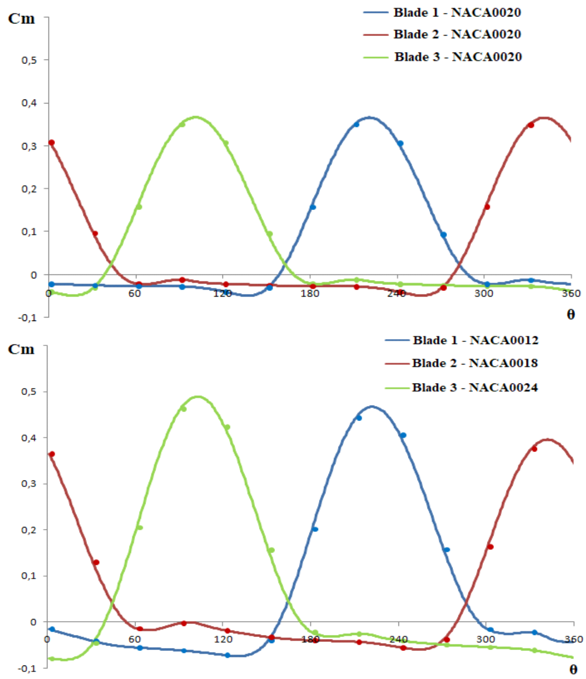

Fig. 6. Variation of torque coefficient, TSR = 2.5: (a) baseline, (b) proposed.

Visualizing the vorticity magnitude in CFD simulations is a useful method for understanding and depicting flow characteristics, such as the presence of swirl, rotational motion, and vortices in fluid flows. High vorticity magnitude indicates strong vortices, whereas low vorticity suggests more uniform or irrotational flow. For each case, the vorticity of the speed (velocity curl) shows the region where vertices are prone to form in the rotor region. Vorticity magnitude contours for both cases are displayed in Figure 7 at the nominal position when TSR is 2.5. Power coefficient is an important indicator in the wind energy sector because it helps measure how well a wind turbine converts wind energy into usable electricity. One of the main objectives in designing more environmentally friendly and economically competitive wind energy systems is to use VAWTs with greater C_p values. C_p is applied in CFD simulations to evaluate a VAWT design's performance at different wind speeds. A VAWT's operation and design may be optimized to improve energy extraction and efficiency by examining how C_p varies with wind speed and condition. Upon exploring the new geometry, it is possible to see that the change in the total power coefficient indicates an improvement over the base geometry brought in by the high TSR area.

V. CONCLUSIONS

The growing demand for energy can heavily diminish power availability, and considering the objective to completely eliminate burning fuels as an energy source, the only viable means of generating electricity are renewable energy sources. So, wind turbines emerge as a feasible alternative to tackle climate change and develop a sustainable energy grid which justifies why VAWTs (Darrieus-type) are becoming increasingly popular.

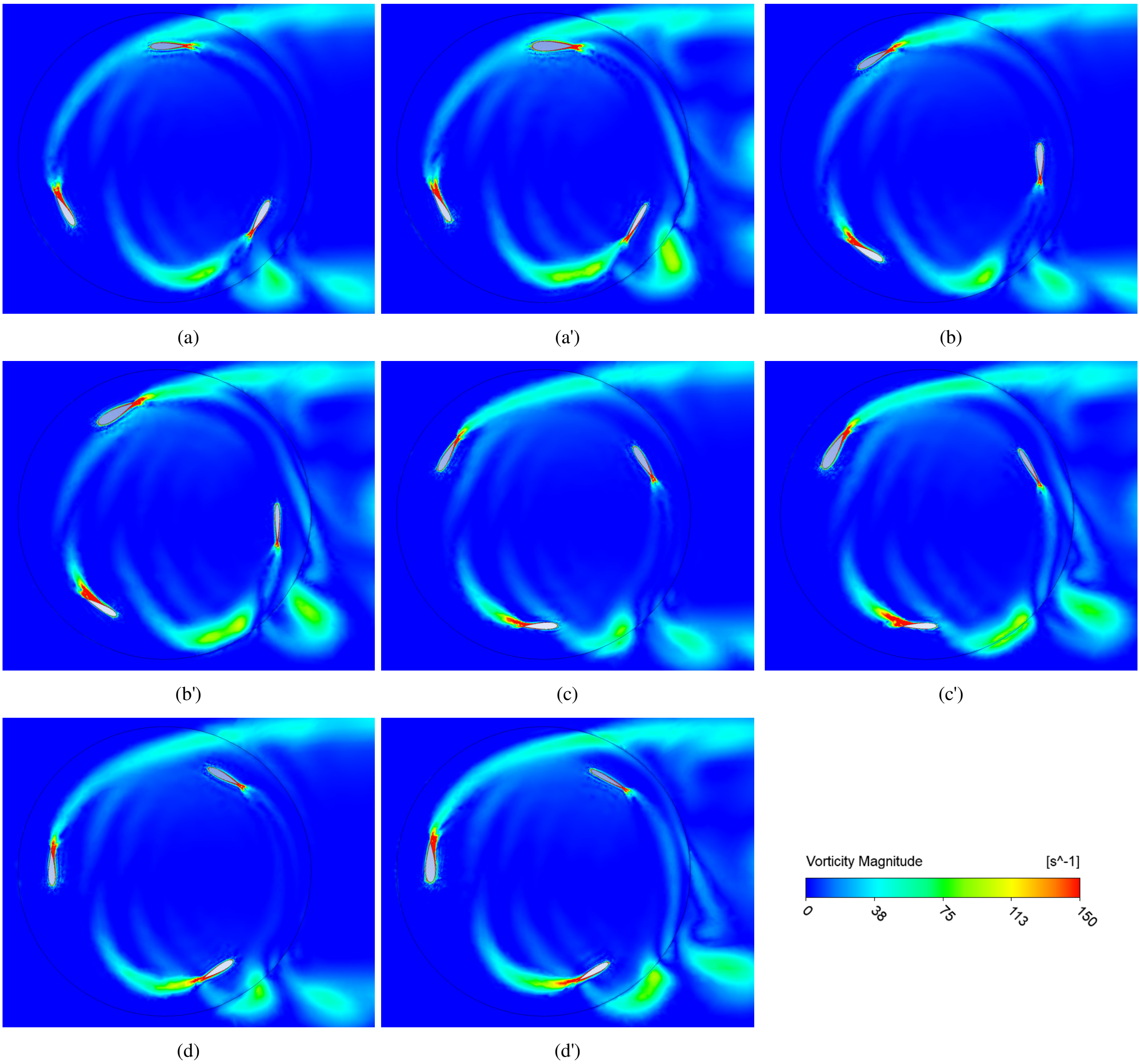

Fig. 7. Vorticity magnitude (a) baseline at $\theta = 0°$, (a') new geometry at $\theta = 0°$, (b) baseline at $\theta = 30°$, (b') new geometry at $\theta = 30°$, (c) baseline at $\theta = 60°$, (c') new geometry at $\theta = 60°$, (d) baseline at $\theta = 90°$, (b') new geometry at $\theta = 90°$.

Unsteady Reynolds Averaged Navier-Stokes (URANS) studies are successfully completed in this paper for the comparison of two vertical axis wind turbine layouts under wind conditions of 12 m/s using the CFD software ANSYS Fluent. Each turbine has 3 blades positioned at the same radius, with the exception of the second turbine, which has a distinct airfoil shape for each blade. All simulations were performed in 2D, with 6 TSRs ranging from 1 to 3. As a consequence, for every numerically examined example, the entire torque coefficient values for full 360 degrees circle are displayed. The vorticity magnitude distribution for each wind turbine design was predicted by the simulations.

Furthermore, the new geometry analyzed in this paper has a better overall performance in high TSR regions than the base geometry. The former reaches higher values of torque coefficient and power coefficient, and results in a higher power output for the same wind conditions as the base geometry turbine. The wind kinetic energy resources found in the urban areas, along with the small sizes of these devices and their silent operation make these wind turbines a very attractive choice for any household user. This is because they lead to a certain degree of power independence and contribute to the reduction of the greenhouse gases emissions.

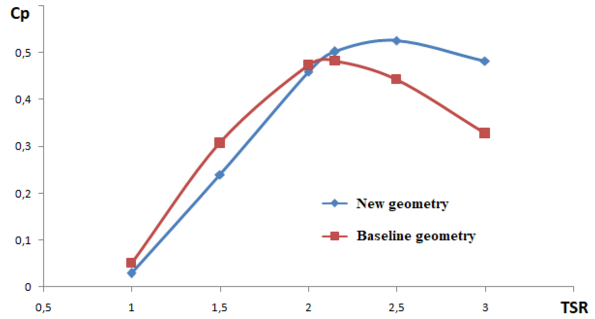

Fig. 8. C_p variation.

By using a new turbine profile with varied chord lengths and airfoils like the geometry studied in this paper, the performance of future generations of small urban-sized VAWTs will augment and make Darrieus-type VAWTs an even more attractive solution. In the future, an optimization with genetic algorithms will be performed in order to design a small prototype that can be tested under real-life settings in an experimental testing facility near the Black Sea where the wind speed is suitable for wind turbines.

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REFERENCES

[1] G. Boluk and M. Mert, "Fossil & renewable energy consumption, GHGs (greenhouse gases) and economic growth: Evidence from a panel of EU (European Union) countries," *Energy*, vol. 74, pp. 439–446, Sep. 2014, https://doi.org/10.1016/j.energy.2014.07.008.

[2] P. K. Ozili and E. Ozen, "Global Energy Crisis: Impact on The Global Economy," in *The Impact of Climate Change and Sustainability Standards on the Insurance Market*, New York, NY, USA: Wiley, 2023, pp. 85–89.

[3] N. Lienhard, R. Mutschler, L. Leenders, and M. Rudisuli, "Concurrent deficit and surplus situations in the future renewable Swiss and European electricity system," *Energy Strategy Reviews*, vol. 46, Mar. 2023, Art. no. 101036, https://doi.org/10.1016/j.esr.2022.101036.

[4] J. B. V. Subrahmanyam, P. Alluvada, Bandana, K. Bhanupriya, and C. Shashidhar, "Renewable Energy Systems: Development and Perspectives of a Hybrid Solar-Wind System," *Engineering, Technology & Applied Science Research*, vol. 2, no. 1, pp. 177–181, Feb. 2012, https://doi.org/10.48084/etasr.104.

[5] R. Harmsen, B. Wesselink, W. Eichhammer, and E. Worrell, "The unrecognized contribution of renewable energy to Europe's energy savings target," *Energy Policy*, vol. 39, no. 6, pp. 3425–3433, Jun. 2011, https://doi.org/10.1016/j.enpol.2011.03.040.

[6] "Energy statistics - an overview." https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_statistics_-_an_.

[7] K. Larsen, "Recycling wind turbine blades," *Renewable Energy Focus*, vol. 9, no. 7, pp. 70–73, Jan. 2009, https://doi.org/10.1016/S1755-0084(09)70045-6.

[8] M. R. Islam, S. Mekhilef, and R. Saidur, "Progress and recent trends of wind energy technology," *Renewable and Sustainable Energy Reviews*, vol. 21, pp. 456–468, May 2013, https://doi.org/10.1016/j.rser.2013.01.007.

[9] G. Dragomir, A. Serban, G. Nastase, and A. I. Brezeanu, "Wind energy in Romania: A review from 2009 to 2016," *Renewable and Sustainable Energy Reviews*, vol. 64, pp. 129–143, Oct. 2016, https://doi.org/10.1016/j.rser.2016.05.080.

[10] J. Dujardin, A. Kahl, B. Kruyt, S. Bartlett, and M. Lehning, "Interplay between photovoltaic, wind energy and storage hydropower in a fully renewable Switzerland," *Energy*, vol. 135, pp. 513–525, Sep. 2017, https://doi.org/10.1016/j.energy.2017.06.092.

[11] X. Changliang and S. Zhanfeng, "Wind energy in China: Current scenario and future perspectives," *Renewable and Sustainable Energy Reviews*, vol. 13, no. 8, pp. 1966–1974, Oct. 2009, https://doi.org/10.1016/j.rser.2009.01.004.

[12] "China Has Switched On the Largest Wind Turbine Ever," *Popular Mechanics*, Jul. 27, 2023. https://www.popularmechanics.com/science/green-tech/a44632369/china-turns-on-worlds-largest-turbine.

[13] L. Dawid, "Perspectives on offshore wind farms development in chosen countries of European Union," *Journal of Water and Land Development*, no. 38, pp. 27–34, 2018, https://doi.org/10.2478/jwld-2018-0039.

[14] "Wind energy in Europe: 2022 Statistics and the outlook for 2023-2027," *WindEurope*. https://windeurope.org/intelligence-platform/product/wind-energy-in-europe-2022-statistics-and-the-outlook-for-2023-2027.

[15] M. Ali, A. Gherissi, and Y. Altaharwah, "Experimental and simulation study on a rooftop vertical-axis wind turbine," *Open Engineering*, vol. 13, Jun. 2023, Art. no. 20220465, https://doi.org/10.1515/eng-2022-0465.

[16] T. S. Sithole, L. Snyman, V. R. Veeredhi, and T. Sithebe, "Implementation and Evaluation of a Low Speed and Self-Regulating Small Wind Turbine for Urban Areas in South Africa," *Engineering, Technology & Applied Science Research*, vol. 13, no. 2, pp. 10553–10558, Apr. 2023, https://doi.org/10.48084/etasr.5697.

[17] S. J. Kooiman and S. W. Tullis, "Response of a Vertical Axis Wind Turbine to Time Varying Wind Conditions Found within the Urban Environment," *Wind Engineering*, vol. 34, no. 4, pp. 389–401, Jun. 2010, https://doi.org/10.1260/0309-524X.34.4.389.

[18] A. Dessoky, T. Lutz, G. Bangga, and E. Krämer, "Computational studies on Darrieus VAWT noise mechanisms employing a high order DDES model," *Renewable Energy*, vol. 143, pp. 404–425, Dec. 2019, https://doi.org/10.1016/j.renene.2019.04.133.

[19] P. D. Abd Aziz, A. K. R. Mohamad, F. Z. Hamidon, N. Mohamad, N. Salleh, and N. M. Yunus, "A simulation study on airfoils using VAWT design for low wind speed application," in *4th International Conference on Engineering Technology and Technopreneuship*, Kuala Lumpur, Malaysia, Aug. 2014, pp. 105–109, https://doi.org/10.1109/ICE2T.2014.7006228.

[20] F. Kanyako and I. Janajreh, "Vertical Axis Wind Turbine performance prediction for low wind speed environment," in *IEEE Innovations in Technology Conference*, Warwick, RI, USA, Dec. 2014, pp. 1–10, https://doi.org/10.1109/InnoTek.2014.6877366.

[21] N. Korprasertsak and T. Leephakpreeda, "Analysis and optimal design of wind boosters for Vertical Axis Wind Turbines at low wind speed," *Journal of Wind Engineering and Industrial Aerodynamics*, vol. 159, pp. 9–18, Dec. 2016, https://doi.org/10.1016/j.jweia.2016.10.007.

[22] Z. Ferdous, M. Islam, and M. Ali, "A comparative analysis of aerodynamic charecteristics of a vertical axis vane type wind turbine overeven and odd number of blades," *Journal of Mechanical Engineering*, vol. 45, no. 1, pp. 14–18, Jul. 2015, https://doi.org/10.3329/jme.v45i1.24378.

[23] P. Jaohindy, F. Garde, and A. Bastide, "Aerodynamic and mechanical system modeling of a vertical axis wind turbine (VAWT)," in *International Conference on Electrical and Control Engineering*, Yichang, China, Sep. 2011, pp. 5189–5192, https://doi.org/10.1109/ICECENG.2011.6058214.

[24] I. Malael and I. O. Bucur, "Numerical Evaluation of the Flow around a New Vertical Axis Wind Turbine Concept," *Sustainability*, vol. 13, no. 16, Jan. 2021, Art. no. 9012, https://doi.org/10.3390/su13169012.

[25] M. Jafaryar, R. Kamrani, M. Gorji-Bandpy, M. Hatami, and D. D. Ganji, "Numerical optimization of the asymmetric blades mounted on a vertical axis cross-flow wind turbine," *International Communications in Heat*

and Mass Transfer, vol. 70, pp. 93–104, Jan. 2016, https://doi.org/10.1016/j.icheatmasstransfer.2015.12.003.

[26] H. Nawir, M. R. Djalal, A. A. Hasri, and A. W. Fauziah, "Modification of the Vertical Axis with Variations in the Number of Blades of the Savonius Wind Turbine," *Journal of Advanced Technology and Multidiscipline*, vol. 2, no. 1, pp. 1–8, 2023.

[27] I. Malael and V. Dragan, "Numerical and Experimental Efficiency Evaluation of a Counter-Rotating Vertical Axis Wind Turbine," *Engineering, Technology & Applied Science Research*, vol. 8, no. 4, pp. 3282–3286, Aug. 2018, https://doi.org/10.48084/etasr.2231.

[28] L. Battisti, E. Benini, A. Brighenti, S. Dell'Anna, and M. Raciti Castelli, "Small wind turbine effectiveness in the urban environment," *Renewable Energy*, vol. 129, pp. 102–113, Dec. 2018, https://doi.org/10.1016/j.renene.2018.05.062.

[29] J. M. Ramirez and M. Saravia, "Assessment of Reynolds-averaged Navier–Stokes method for modeling the startup regime of a Darrieus rotor," *Physics of Fluids*, vol. 33, no. 3, Mar. 2021, Art. no. 037125, https://doi.org/10.1063/5.0045083.

[30] L. Wang, A. Kolios, T. Nishino, P.-L. Delafin, and T. Bird, "Structural optimisation of vertical-axis wind turbine composite blades based on finite element analysis and genetic algorithm," *Composite Structures*, vol. 153, pp. 123–138, Oct. 2016, https://doi.org/10.1016/j.compstruct.2016.06.003.

[31] T. D. Ivanov, A. M. Simonovic, J. S. Svorcan, and O. M. Pekovic, "VAWT optimization using genetic algorithm and CST airfoil parameterization," *FME Transactions*, vol. 45, no. 1, pp. 26–31, 2017, https://doi.org/10.5937/fmet1701026I.

[32] G. B. Eke and J. I. Onyewudiala, "Optimization of Wind Turbine Blades Using Genetic Algorithm," *Global Journal of Researches in Engineering*, vol. 10, no. 7, pp. 22–26, 2010.

[33] M.-J. Chern, D. Goytom Tewolde, C.-C. Kao, and N. Vaziri, "Vertical-Axis Wind Turbine Blade-Shape Optimization Using a Genetic Algorithm and Direct-Forcing Immersed Boundary Method," *Journal of Energy Engineering*, vol. 147, no. 2, Apr. 2021, Art. no. 04020091, https://doi.org/10.1061/(ASCE)EY.1943-7897.0000741.

[34] N. Ma *et al.*, "Airfoil optimization to improve power performance of a high-solidity vertical axis wind turbine at a moderate tip speed ratio," *Energy*, vol. 150, pp. 236–252, May 2018, https://doi.org/10.1016/j.energy.2018.02.115.

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Dan Glasberg was born in 2001. He studies Aerospace Engineering at the Politehnica University of Bucharest, specializing in propulsion systems. With experience in CAD design (CATIA V5, AutoCAD) he has worked on projects where ANSYS Fluent and STAR-CCM+ are used to deepen his skills in numerical simulations and to gain experience in CFD. He has also participated at rocket-modelling contests and at the Strength of Materials Professional Contest "C.C Teodorescu". Currently he is working on his diploma project where the influence of an injectors' behavior on the flame and flow in the combustion chamber of a turbojet engine is studied.

Ion Malael was born in 1985. He is a member of RRDI COMOTI since 2009. He obtained a PhD in Aerospace Engineering in 2014 and a Master in Software in Aerospace Engineering in 2011. He has worked as an Aviation Engineer – Aerospace Constructions, Aerospace Engineering Faculty at UPB – 2009. He has experience in CFD (ANSYS CFX, Fluent), CAD design (CATIA V5, Solidworks, AutoCAD), and wind turbine experimentation. Most of the projects in which he has participated were in the field of bladed machines, mainly focusing on improving their performance. He has published over 50 scientific articles in both conferences and specialized journals. From 2009 he has been involved in over 30 national and international research projects. He reviews around 20 papers per year.