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Review of the doctoral dissertation of Ms. MSc Eng. Shivangi Sachar entitled: "Performance and Noise Sources of a Savonius Wind Turbine in an Urban Environment"

The legal basis for preparing this review is letter No. RN-521.7.2025 dated December 18, 2025.

1. Title of the doctoral dissertation forming the basis for the current application for the degree of Doctor.

The basis for applying for the degree of Doctor in the current procedure is the doctoral dissertation of Ms. MSc Eng. Shivangi Sachar entitled: "Performance and Noise Sources of a Savonius Wind Turbine in an Urban Environment." The supervisor of the dissertation is Prof. Dr. Hab. Eng. Paweł Flaszyński.

2. General description of the doctoral dissertation, including information on its individual components.

The doctoral dissertation of Ms. MSc Eng. Shivangi Sachar entitled **"Performance and Noise Sources of a Savonius Wind Turbine in an Urban Environment"**, submitted for evaluation, comprises a total of 197 pages, of which the main content occupies 175 pages. The remaining pages include: the title page, acknowledgements, abstracts in English and Polish, table of contents, a list of key notations and symbols, lists of figures and tables, three appendices labeled A, B, and C, and the bibliography. The main content is divided into six chapters.

The abstract presents the issues related to the use of wind energy in an urban environment, the main assumptions and objectives of the doctoral dissertation, as well as the research hypothesis. The author focuses on analyzing the applicability and efficiency of small-scale wind turbines, in particular vertical-axis Savonius turbines, taking into account both energy and acoustic aspects. The work employs experimental, computational, and analytical methods, including wind tunnel and prototype testing, CFD simulations, and acoustic measurements using microphones and microphone arrays. The abstract also highlights an innovative element of the work, namely the analysis of a double-rotor Savonius configuration, and clearly outlines the structure of the dissertation. Overall, the dissertation provides the reader with a clear understanding of the scope of the research, the methods employed, and the contribution of the work to the development of urban wind energy.

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Part 1 of the dissertation ("INTRODUCTION") consists of 4 subsections.

Chapter 1.1 ("Introduction and Background") introduces the reader to the topic of wind energy, with particular emphasis on its application in urban environments. The motivation for the research is presented, arising from the growing demand for energy, urbanization, and the need to implement quiet and renewable energy sources. The chapter discusses the importance of wind characteristics and the influence of environmental conditions on the selection of turbines and installation sites. It also includes a review of the evolution of wind energy and the physical fundamentals of wind formation. Special attention is given to the classification of wind turbines, highlighting the differences between vertical-axis and horizontal-axis designs. Darrieus, Savonius, and hybrid turbines are briefly characterized, emphasizing their suitability for urban conditions. Particular emphasis is placed on the significance of noise levels generated by turbines in urban areas, noting that the low noise emissions of Savonius and other VAWTs are an important factor in increasing social acceptance.

Chapter 1.2 ("Fundamentals of Wind Turbine") presents the basic principles of wind turbine operation and the mechanisms of converting wind energy into useful energy. It discusses the dependence of available wind power on wind speed, air density, and rotor area, considering the effects of atmospheric conditions and altitude on air density. The chapter also covers the dynamics of airflow through the rotor, including air stream expansion and the formation of turbulence behind the turbine. The Betz law is explained, and the concepts of the power coefficient (Cp) and tip-speed ratio (TSR) are introduced as key parameters for turbine evaluation. Special attention is given to comparing the performance of different types of turbines: HAWT, Darrieus, Savonius, and their hybrid configurations. It is noted that Savonius turbines achieve maximum torque at low TSR, enable rapid startup, operate efficiently in weak or variable wind, and their low noise level makes them a practical solution for urban environments.

Chapter 1.3 ("Urban Wind Power: Outline") focuses on issues related to the use of wind energy in urban areas. It discusses wind characteristics in cities, taking into account the influence of buildings, trees, and other obstacles on wind speed, turbulence, and velocity profiles. Methods for assessing wind potential are presented, including the application of probability distributions (e.g., Weibull) and statistical methods for predicting wind energy. The chapter reviews various turbine types suitable for urban conditions, with particular emphasis on small vertical-axis wind turbines (VAWTs), such as Savonius and Darrieus turbines, highlighting their advantages in terms of efficiency in low wind, ease of installation and maintenance, and low noise levels. Special attention is given to turbine noise, its mechanical and aerodynamic sources, and the importance of reducing noise emissions for social acceptance and turbine design in urban environments.

Chapter 1.4 ("Thesis Contents") presents the definition of the research subject, which is the vertical-axis Savonius wind turbine, and provides a general characterization of the scope of the conducted research. The author formulates and discusses five individual research tasks that fall within the scope of the dissertation.

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Part 2 of the dissertation ("METHODS UTILIZED IN THIS THESIS") consists of 3 subsections.

Chapter 2.1 ("Wind Dynamics and Wind Turbine Site Selection") presents issues related to wind characteristics and their significance for planning wind turbine locations. It discusses the random and time-varying nature of wind, including the effects of daily, seasonal, and interannual fluctuations on the power generated by turbines. Basic methods of wind data analysis are presented, including the use of the Weibull distribution to describe the probability of different wind speeds, and the importance of selected parameters for the shape of the distribution and the mean wind speed. The chapter also addresses the effects of measurement height and terrain roughness on wind speed, as well as statistical methods for evaluating the fit of theoretical distributions to observational data, including MAPE, RMSE, R^2, and χ^2. The author emphasizes that a precise analysis of wind in time and space is crucial for selecting optimal turbine locations, maximizing energy efficiency, and ensuring the safety and effectiveness of installations.

Chapter 2.2 ("Numerical Analysis") focuses on numerical methods used to analyze airflow around wind turbines. It discusses the fundamental governing equations of flow, including the mass, momentum, and energy balance equations, along with additional equations of state for pressure and temperature, assuming an ideal gas. The concept of turbulent flow is introduced, along with the Reynolds number criterion and its significance in determining flow characteristics. Turbulence models used in CFD are discussed, including the RANS approach and the k-ω M-SST model.

Chapter 2.3 ("Wind Turbine Noise") presents key information on the measurement and analysis of wind turbine noise. The chapter discusses the advantages and limitations of single-microphone measurements and introduces delay-and-sum beamforming and the creation of scanning point grids for microphone arrays. Conventional frequency-domain beamforming (CFDBF) is described, along with issues such as sidelobes, background noise, and methods of noise suppression. The chapter also covers the evaluation of the total acoustic power of sources using the Source Power Integration (SPI) technique.

Part 3 of the dissertation ("PERFORMANCE ANALYSIS: SAVONIUS WIND TURBINES") consists of 3 subsections.

Chapter 3.1 ("Literature Review and Analysis of Characteristics") presents a literature review on Savonius turbines, with particular emphasis on aerodynamic and acoustic parameters. The main factors affecting performance and generated noise are discussed, such as rotor geometry, number of blades, twist angle, overlap ratio, aspect ratio, and rotor segmentation. Examples of modern SVAWTs are presented, and the research objects are described: single- and five-segment Savonius rotors, with identical basic dimensions enabling a relative comparison of their performance and acoustic characteristics.

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Chapter 3.2 ("Numerical Simulations of Savonius Rotor") describes the numerical model of the Savonius turbine developed to obtain performance and torque characteristics across the full TSR range. Two-dimensional, unsteady RANS simulations using the k-ω M-SST turbulence model and sliding mesh technique are discussed. The chapter presents the geometry and computational mesh, boundary conditions, multigrid strategy, mesh convergence analysis, and selection of temporal simulation parameters. The study is divided into free-stream simulations and simulations in a so-called test section, with rotors positioned at different distances from the airflow outlet. Model validation was performed based on literature data (Blackwell).

Chapter 3.3 ("Experimental Evaluation of Performance Characteristics and Rotor Segmentation") presents the author's experimental investigations of Savonius turbine performance, including single- and five-segment rotors. The influence of rotor shaft position relative to the test section outlet on the power coefficient (Cp) is discussed, highlighting the significance of blockage effects and flow acceleration caused by the geometric constraints of the test section. Results for both rotor types are compared, showing higher efficiency of the single-segment rotor across the full TSR range, due to lower aerodynamic losses and simpler flow patterns. The chapter emphasizes the necessity of validating numerical simulations with experimental data and the role of rotor positioning and segmentation in accurately assessing aerodynamic characteristics and designing turbines for urban applications.

Part 4 of the dissertation ("EXPERIMENTAL ACOUSTICS ASSESSMENT OF SAVONIUS VAWT") consists of 2 subsections.

Chapter 4.1 ("Effect of Rotor Segmentation on Acoustics and its Performance") presents experimental investigations of noise generated by single- and five-segment rotors using a single microphone under various load conditions. The laboratory setup and measurement procedure are described, followed by results across the full frequency range. The study showed that the single-segment rotor generates more acoustic energy at low frequencies but also achieves higher efficiency (Cp). The five-segment rotor produces lower noise, with acoustic energy shifted toward higher frequencies, at the expense of reduced efficiency. A psychoacoustic analysis was also performed, including indicators such as fluctuation strength, roughness, and sharpness.

Chapter 4.2 ("Noise Source Localization") focuses on the localization of noise sources in the single-segment Savonius turbine. The research setup, measurement equipment (Bionic M-112 microphone array), and measurement methodology are described, followed by results for two cases: loaded and unloaded rotor. The application of beamforming and the Source Power Integration (SPI) technique is crucial for determining the levels of distributed sources. The results showed that rotor noise dominates at low frequencies (up to approximately 2 kHz), depends on load and wind speed, and the main noise sources are located on the downstream side of the blade and in the rotor mounting area. Noise level scaling with wind speed was also observed, as well as higher noise emission during free rotation of the rotor, which is relevant for evaluating acoustic emissions under emergency conditions or wind peaks.

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Part 5 of the dissertation ("ANALYSIS OF URBAN ENVIRONMENT AND WIND TURBINES") consists of 2 subsections.

Chapter 5.1 ("Wind Potential Assessment: Urban Environment") presents an analysis of wind potential in urban and suburban environments at selected locations in the United Kingdom (Nottingham) and Poland (Gdańsk, Przywidz). The methodology for collecting and analyzing wind data is discussed, including the determination of mean wind speeds, turbulence intensity, and the assessment of wind power density and energy. Different probability distribution functions (PDFs), including Weibull, Rayleigh, and Gamma, were compared, and based on a goodness-of-fit analysis, the Weibull distribution was selected as the most suitable model. An additional element of the chapter is a review and selection of small turbines suitable for urban conditions, considering their efficiency at typical wind speeds and the turbulence intensity characteristic of built-up areas.

Chapter 5.2 ("Experimental Analysis of an Innovative Twin-Rotor Savonius Type Wind Turbine") presents experimental investigations of an innovative Savonius turbine prototype in a twin-rotor configuration. Tests were conducted both in an urban environment – on the roof of the IMP-PAN building – and in suburban conditions using a full-scale power plant in Przywidz. The chapter provides a detailed description of the turbine configuration, including the use of guiding plates, rotor segmentation, and prototype dimensions. The data collection method is also discussed, including measurements of voltage, current, and rotor rotational speed, as well as the characteristics of the generator load control algorithm. For the urban installation, results are presented for an average wind speed of approximately 5-5.5 m/s and high turbulence intensity. The chapter shows the power generated by individual rotors, TSR analysis, the impact of wind fluctuations on rotor behavior, and the turbine's response delay to changes in wind speed. Opportunities for improving efficiency through modification of the rotor load control algorithm are also discussed. For the suburban installation, a full-scale power plant is described, consisting of three twin-rotor turbine sets, each with four rotors and four generators. TSR and power characteristics for individual turbines are presented, highlighting the influence of turbine positioning relative to wind direction and aerodynamic shadowing effects. The chapter also addresses delays in rotor response to sudden changes in wind speed and the challenges associated with measurement and control under real operating conditions.

Part 6 of the dissertation (CONCLUSION AND FUTURE WORK) consists of 2 unnumbered sections.

The **Conclusions** section synthesizes the entirety of the conducted research, including the analysis of wind potential in urban environments, experimental and numerical investigations of Savonius rotors, noise emission assessment, and field tests of the innovative twin-rotor turbine. The author organizes the obtained results, relating them to the objectives formulated in Section 1.4, and identifies the relationships between aerodynamic performance, turbine operating conditions, and acoustic impact. The summary emphasizes the importance of field and acoustic studies for the application of SVAWTs in urban environments and indicates directions for further optimization, particularly in the areas of control strategies and operation under variable wind conditions. The section is complemented by a summary of the main achievements of the work and its contribution to the state of knowledge.

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The **Future Work** section contains a list of five areas that the author considers worthy of further investigation and that constitute a natural continuation of the research described in the dissertation.

3. Assessment of the Literature Used in the Doctoral Dissertation

The dissertation's bibliography is very extensive, comprising a total of 227 items. Most of the sources are recent, published within the last 10 years. Older references are also included, primarily classic works in aerodynamics and statistics. The bibliography is thematically coherent and well-aligned with the subject of the dissertation. The majority of the publications are from high-impact journals in the fields of wind energy and aeroacoustics, indicating a solid scientific foundation. The inclusion of a few less prestigious sources (websites, blogs, reports) is acceptable in the context of commercial and technological examples.

4. Identification and Evaluation of the Candidate's Research Objective

The objective of the dissertation is a comprehensive investigation of Savonius wind turbines, with particular emphasis on their application in urban environments. This includes the assessment of efficiency, aerodynamic characteristics, noise emissions, the impact of rotor segmentation, and the evaluation of an innovative twin-rotor configuration, both under laboratory conditions and in real urban and suburban locations, with the aim of developing practical solutions for urban wind energy systems.

The formulation of the objective in Section 1.4.1 is extensive and descriptive, lacking a concise statement that clearly defines the essence of the research. There is no clear prioritization of the topics, which makes it difficult to determine the main focus and does not explicitly indicate the original contribution of the author. As a result, while the objective is broad and ambitious, it appears diffuse, making it challenging to infer measurable outcomes that the author intends to achieve.

5. Evaluation of the Dissertation Sections Addressing the Discussion of Research Results

Part 1 fulfills its introductory role and establishes a coherent foundation for the further analyses presented in the dissertation. The selection of literature and the manner of presenting the narrative demonstrate the author's solid understanding of wind energy, particularly in the context of urban environments. The introduction of key concepts and parameters used in later sections is justified and consistently supports subsequent numerical and experimental considerations. Although the theoretical discussion is somewhat limited in scope, it is sufficient with regard to the objectives of the dissertation. The author appropriately emphasizes the importance of efficiency and noise as criteria for evaluating turbines intended for urban applications, which aligns fully with the dissertation title. The structure of the section is clear, and the logical flow facilitates comprehension and prepares the reader for more detailed analyses.

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Part 2 serves as the theoretical and methodological foundation of the work, but it addresses this purpose unevenly. The strongest element is the description of wind data analysis methods, which is detailed, technically accurate, and covers a wide range of statistical tools. The presentation indicates good familiarity with measurement data processing and interpretation in the context of wind energy.

A weaker aspect of Part 2 is the section on numerical analysis. The description of the governing flow equations is brief and presented in an unusual format. While this may reflect the documentation style of the software used, it is difficult to confirm due to the lack of proper bibliographic references. Errors appear in the presented equations, and the physical quantities involved are insufficiently described. The relatively low level of content presentation in this section may raise doubts about the author's full understanding of the discussed topics. This is the least polished element of the dissertation, which is also reflected in the references: of the 227 bibliographic entries in the dissertation, only 2 are cited in this section, and only in reference to the turbulence model used. The absence of references to the CFD software documentation further weakens the scientific coherence and clarity of the presented material. The section on acoustics is adequate for supporting the subsequent studies presented in the dissertation. Key concepts and noise analysis methods are introduced, although the text occasionally loses clarity and could benefit from more structured presentation.

Despite these shortcomings, Part 2 provides the necessary theoretical foundation for conducting numerical and experimental investigations, though the scientific rigor varies significantly between different topics.

Part 3 of the dissertation is methodologically sound. The description of the research objects is clear and comprehensive. The numerical model of the Savonius turbine is consistent, and the computational assumptions fall within the standards typically applied in CFD analyses of such systems. The choice of a two-dimensional, unsteady RANS model, the size of the computational domain, and the use of the k-ω M-SST turbulence model are all appropriate. The inclusion of a mesh convergence analysis and discussion of its influence on the results is positively noted. Boundary conditions and simulation parameters are mostly sufficient, although, for example, a clear justification for the chosen inlet velocity is missing.

A minor drawback is the assumption that the configuration of the wind tunnel and the introduced test section are obvious to the reader. It is unclear why the test section description was moved to Appendix B, as this arrangement reduces chapter clarity. A more effective approach would be to provide a brief description of the tunnel, including the test section, to present the research setup comprehensively rather than focusing only on rotor geometry. This would improve the coherence of the work, since Figures 3.2.1 and 3.2.4 depict the full flow system, not just the rotors. It is possible that the description was moved to the appendix because the same setup was used for acoustic studies described in the next part of the dissertation.

The author refers to experimental studies of single- and five-segment turbines, but the dissertation lacks a clear and consistent description of the experimental plan. Assumptions, the set of controlled parameters, their variation ranges, measurement accuracy, and procedures, including the number of

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repetitions, are not clearly defined. It is also surprising that the results of the author's own experiments were used very sparingly (mainly in Table 3.3.1), while numerical model validation relied exclusively on literature data (Blackwell). Additionally, the term "experimental study" is used inconsistently, referring both to the author's own experiments and to literature results, which complicates evaluation of the content.

Despite these issues, the overall logic is correct and consistent with good CFD practice: the computational model was first validated against literature data, followed by controlled modifications of the model configuration to deepen understanding of system behavior.

The analysis and interpretation of the numerical results presented in Section 3.2 are also positively evaluated, even though the author does not refer to her own experimental results and limits the discussion to the constraints imposed by Betz's law. Causes of overestimated power coefficient values, resulting from simplified and favorable flow conditions in the baseline computational domain, are correctly identified. The subsequent simulations in a modified domain configuration, described in Section 3.3, represent a methodologically justified step. Although this did not significantly improve the quantitative agreement between experimental and simulated results, the attempt and its careful analysis deserve positive recognition.

Overall, the numerical model correctly reproduces the qualitative trends of Cp versus TSR and rotor position, though it still overestimates absolute values compared to experimental data. Consequently, the model is primarily useful for analyzing trends and the influence of geometric parameters and flow conditions, but not for precise quantitative prediction of turbine performance. In the context and scope of the doctoral dissertation, this application is adequate and sufficient.

Part 4 describes experimental acoustic studies conducted in the same wind tunnel as in Part 3, using the same single- and five-segment rotors, ensuring logical consistency between the two chapters. The inclusion of four test cases is reasonable and scientifically justified. The experiment description is detailed, including data analysis methods, number of repetitions, measurement equipment and accuracy, and software used for data analysis. The results are presented clearly, with a high-quality description and interpretation. An important element, particularly in the context of urban wind energy, is the discussion of the psychoacoustic effects of rotor-generated noise under different operating conditions.

A valuable complement to single-microphone acoustic studies is the investigation of the single-segment rotor using a microphone array and the advanced Source Power Integration technique. The descriptions of the experimental setup, instrumentation, and methodology are thorough and exhaustive. The study plan and scope are well thought out, and the inclusion of both loaded and unloaded rotor configurations is fully justified. In addition to sound spectra and general characteristics such as Overall Sound Pressure Level, the noise source maps are a particularly valuable element, allowing identification of the most significant sound sources. It should also be noted that these studies were conducted at a reputable international research institution.

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A minor shortcoming is the lack of discussion regarding potential turbine locations in urban areas. It can be assumed that turbines will primarily be mounted on building rooftops, with noise propagation occurring both as airborne sound and as structural vibrations. Furthermore, noise propagation differs between sloped and flat roofs, particularly if turbines are not mounted at the roof edge. Issues such as acoustic shadowing and reflections from roof surfaces or nearby buildings and structures also arise.

Part 5 is coherent and methodologically correct, continuing the logical sequence of previous chapters. The analysis of wind potential in urban and suburban areas is relatively clear. The use of various probability distribution functions, including Weibull, Rayleigh, and Gamma, is well justified and consistently linked to the theoretical background presented in Chapter 2. The selection of measurement locations in Poland (based on the author's research site) and the UK (through the ZEPHYR project collaboration) and the comparison of wind conditions between them are sensible and scientifically justified. Parameters such as mean wind speed, turbulence intensity, and wind power density allow for a good assessment of the energy potential of the studied areas. An important element is the summary of available small wind turbines and their parameters in the context of urban applications.

Chapter 5.2 provides a natural and valuable extension of the wind potential analyses presented in Chapter 5.1, moving the discussion from resource assessment to real turbine performance in field conditions. The description of both installations is detailed and technically accurate. The author clearly presents turbine geometry, the use of guiding plates, rotor segmentation, and basic construction parameters, allowing assessment of the innovation of the proposed solution and its comparison with conventional Savonius turbines. The precise description of measurement systems, measured quantities, measurement errors, and sampling frequency is also commendable.

Although preliminary, the full-scale installation tests provide valuable qualitative observations of multi-turbine system performance and aerodynamic interactions. The author appropriately avoids overgeneralization and clearly communicates that the results are indicative, reflecting research maturity. This chapter adds an important applied element to the dissertation, demonstrating practical limitations and opportunities for Savonius turbines in environments with highly variable wind conditions.

The **Conclusions** section is coherent, logical, and scientifically mature. The author effectively integrates results obtained in different parts of the dissertation, avoiding a simple chapter-by-chapter summary in favor of a synthetic interpretation of the findings. Particularly noteworthy is the consistent linking of aerodynamic, acoustic, and operational aspects, along with a realistic assessment of research limitations, especially regarding full-scale tests. The conclusions, which are qualitative in nature, are balanced, well justified by the results, and clearly indicate both the scientific value of the work and its potential practical applications in urban wind energy.

The **Future Work** section is appropriately aligned with the results obtained during the dissertation and the conclusions drawn from them. The author accurately identifies directions for further research, emphasizing the importance of acoustic optimization, rotor control, field tests, and integration of

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turbines into urban environments. The conclusions are logical, well connected to the results, and indicate practical implications for the design and operation of Savonius turbines.

In the conclusions and discussion of future work, the author mentions the need to improve control algorithms. However, it is unclear on what basis this statement is made, since the issue of control algorithms is not described in the dissertation.

Finally, it should be emphasized that the hypothesis formulated in the abstract – stating the need to identify specific characteristics of wind turbines for their effective and socially acceptable integration into urban environments – is appropriate and consistent with the scope of the dissertation. The conducted studies, including wind potential analysis, aerodynamic and acoustic experiments, and field tests of the innovative twin-rotor turbine, allow assessment of the impact of environmental conditions, rotor geometry, and segmentation on performance and noise emissions. In this sense, the hypothesis is confirmed: the results indicate which turbine features are key for efficient operation in urban conditions and social acceptance, fully aligning with the research objectives and the title of the dissertation

Detailed Comments:

1. Throughout the dissertation, not only in Part 1, the same information is repeated multiple times, e.g., regarding the growing interest in wind energy in cities, the potential of Savonius turbines in urban environments, their lower noise levels, or easier startup compared to other designs. Repetition of these points in different sections unnecessarily lengthens the dissertation and reduces readability.
2. Sections 1.4.1 and 1.4.2 repeat the description of the dissertation structure. It would be clearer to present this division in one place, while simultaneously indicating which chapters contain detailed descriptions of each stage.
3. The title of Chapter 2.2 is too general; it would be better to specify the numerical method used in the work, e.g., "Fundamentals of the Finite Volume Method" or "Finite Volume Method: Introduction."
4. Equations 2.2.1-2.2.3 are presented in an unusual format (and without references). Typically, in the CFD context, balance equations are written to emphasize a uniform structure, including temporal, convective, diffusive, and source terms.
5. The use of the term "Navier-Stokes equations" for equations 2.2.1-2.2.3 is incorrect.
6. The description of energy is incorrect. Currently, it seems that the symbol E in equations 2.2.3 and 2.2.5 (with an additional error in the subscript in the latter) represents the same quantity, which is likely not the case.
7. The Kelvin symbol (K) should not be preceded by a degree sign.
8. Providing a definition of the Reynolds number is unnecessary.
9. Equation 2.2.11 contains errors. The notation D^R is misleading, as it suggests that the deformation tensor of a fluid element is calculated differently for laminar and turbulent flows.

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10. In Chapter 2.2.2, it is incorrectly stated that the Lattice-Boltzmann Method (LBM) is meshless. LBM is based on discretizing space into a regular lattice, where the nodes store particle distribution functions that "move" along directions allowed by the lattice model.
11. Chapter 2.2.3 appears incomplete. Only one turbulence model is briefly described, although earlier the text states: "Discussed below are some of the commonly used RANS turbulence models:" (the colon at the end is incorrect).
12. In Section 2.3.1, it would be useful to emphasize that the essential difference between microphone array measurements and single-microphone measurements is the ability to acquire acoustic data from multiple locations simultaneously.
13. Section 2.3.1 lacks a clear definition of a microphone array. It should be clarified whether the term refers to a compact system of several or several dozen microphones placed close together (e.g., on a common frame) or to arbitrarily spaced microphones separated by tens or hundreds of meters.
14. In Section 3.2, the choice of boundary conditions (12 m/s velocity and 293 K temperature) is not justified.
15. The literature review in Section 3.1.1, as well as the fragment titled "Novel SVAWT designs in urban environment," does not fit this part of the dissertation – such information should appear in the introduction. Mixing detailed technical analyses with general information occurs frequently in the dissertation, which is nonstandard and partially reduces clarity.
16. The opening sentence of Chapter 3.2 misrepresents the situation and may mislead the reader: "The first part of the study consists of numerical simulations to verify and validate the numerical model with experimental results." It should clarify that two sets of experimental data are used – both the author's and Blackwell's – and explain why and which data are used in which analyses.
17. The sentence "This data was obtained by wind tunnel tests and was later corrected to match freestream results" is unclear and raises questions: Who corrected the data – Blackwell (as seems likely) or the author? How did Blackwell handle the blockage effect, given that he also used a wind tunnel? Was a similar correction applied to the author's experimental data?
18. In Section 4.1.1, the sentence "For this experimental campaign, the rotors discussed in Section 3.1.1" probably refers to Section 3.1.2.
19. The author often does not justify her choices or the parameter values used. For example, "The microphone was placed at half the height of the rotor at a distance of 0.7 m from the rotor axis" or "The noise measurements were made for four different cases, while the velocity of the test section was fixed at 8.5 m/s." The basis for selecting these numerical values is unclear.
20. The summary contains the sentence: "This thesis set out to investigate the potential and performance of SVAWTs in complex urban settings, where wind conditions are typically less favorable and infrastructure constraints are more pronounced." However, the dissertation contains relatively few references to such infrastructure limitations.
21. The work contains numerous referencing errors – additionally, in the electronic version, references often link to the wrong elements.

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Comments and Questions for the Author:

1. Please provide the correct forms of the equations presented in Chapter 2.2 and indicate the source literature on which they were based.
2. Please explain why the results of your own experimental research were only minimally used in the numerical model validation process, and why they were described in the dissertation in such a general manner.
3. Please address the remarks regarding control algorithms that appear in the conclusions and the Future Work section, and clarify on what basis these remarks were formulated, given that these issues were not the subject of analyses presented in the dissertation.

6. Information on the practical application of the obtained results

The dissertation provides valuable information on the practical possibilities of using Savonius wind turbines in urban environments. The results of field experiments and acoustic analyses allow for the assessment of energy efficiency and the impact of noise on the surroundings, which is important for planning real installations. Although the full-scale studies are preliminary, they indicate both the limitations and potential of twin-rotor turbines, providing useful guidance for designers and operators of urban wind energy systems.

7. Information on any irregularities identified in the evaluated doctoral dissertation

No significant substantive shortcomings were observed in the dissertation. The work is characterized by coherence, a logical structure, and the validity of its conclusions, which confirms its high scientific value.

8. Assessment of whether the dissertation constitutes an original solution to a scientific problem

The dissertation undoubtedly represents an original solution to the scientific problem of analyzing and evaluating Savonius wind turbines in urban environments, with particular emphasis on the influence of design parameters and operating conditions on aerodynamic efficiency and noise emission. The originality of the solutions presented in the dissertation is manifested in particular by:

- the development and execution of experimental performance studies of single- and five-segment Savonius turbines in a wind tunnel;
- the conduct of numerical analyses of the impact of rotor positioning within the test section on its energy performance characteristics;
- the development and implementation of experimental studies of a Savonius turbine in an innovative twin-rotor configuration under field conditions at two locations;

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- the execution of acoustic studies, including both single-microphone measurements and spatial analysis of the acoustic field using a microphone array;
- the statistical processing and interpretation of wind data from several selected locations;
- the integration of aerodynamic, acoustic, and field results into a coherent assessment of the suitability of Savonius turbines for urban applications, along with the identification of directions for further optimization.

9. Assessment of whether the dissertation demonstrates the candidate's general theoretical knowledge in the discipline(s) and the ability to conduct independent scientific or artistic work

The dissertation clearly confirms the Author's extensive theoretical knowledge in the fields of flow aerodynamics, Savonius turbines, wind acoustics, numerical and experimental research methods, and statistical analyses. The work also demonstrates the ability to independently plan and carry out scientific research. These competencies are particularly evident in:

- the development and execution of experimental studies in a wind tunnel and under field conditions for single- and five-segment turbines, including the twin-rotor configuration;
- the application of a coherent methodology for acoustic studies, encompassing single-microphone measurements as well as spatial analysis of the acoustic field using a microphone array, including beamforming and Source Power Integration techniques;
- the combination of experimental studies with CFD numerical analyses (two-dimensional unsteady RANS simulations with the k-ω M-SST turbulence model), enabling assessment of the impact of rotor geometry and flow conditions on aerodynamic characteristics;
- the independent application of statistical methods to analyze wind data, including the selection of the Weibull distribution based on goodness-of-fit analyses and interpretation of results in a practical context;
- the integration of aerodynamic, acoustic, and field results into a coherent assessment of the efficiency and suitability of Savonius turbines for urban applications;
- the ability to critically analyze the literature and justify the assumptions and research parameters adopted, demonstrating the Author's research maturity.

10. Final Opinion

In summary of the review of the doctoral dissertation by MSc. Eng. Shivangi Sachar entitled *"Performance and Noise Sources of a Savonius Wind Turbine in an Urban Environment"*, I state that:

1. The presented material clearly confirms the Author's solid theoretical preparation and her competencies in the fields of flow aerodynamics, wind turbine acoustics, statistical data analysis, and CFD numerical computations. Both the subject of the dissertation and the applied research methods – including wind tunnel experiments, acoustic measurements, and numerical simulations – are fully appropriate for the discipline of mechanical engineering.

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2. The candidate has demonstrated research maturity as well as the ability to independently plan, execute, and analyze experimental and numerical studies, and to present the obtained results clearly and concisely. This evidences her preparedness for conducting further independent scientific work in this field.
3. The obtained results have significant cognitive value for the field of mechanical engineering and provide an original contribution to the study of Savonius turbines, particularly regarding their aerodynamic performance, noise emissions, and potential applications in urban environments. These findings also offer valuable practical guidance for the design and operation of small-scale vertical-axis wind turbines.

In view of the above, I conclude that the doctoral dissertation by MSc. Eng. Shivangi Sachar entitled *"Performance and Noise Sources of a Savonius Wind Turbine in an Urban Environment"* meets the requirements of Article 187 of the Act of 20 July 2018 on Higher Education and Science (Journal of Laws of 20 April 2023, item 742, as amended) and **may serve as a basis for proceeding to the public defence**.

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February 03, 2026