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Research Paper**Vertical Axis Wind-Turbine Noise Barrier- 2****G.G.Meshram****SHEIKH MUNEEB KAMRAN****ADITYA SANTOSH LALE****SAGAR GAJANAN RAIBOLE****ZOEB PARVEZ QAMAR PARVEZ****MOHD ALTMASH AB MATIN****DRGITR (Poly), Amravati, Maharashtra , India****Abstract**

Rapid urbanization and increasing road traffic have created two important environmental challenges: rising energy demand and transportation-related noise pollution. Conventional highway noise barriers reduce the propagation of traffic noise but generally do not provide an additional energy-producing function. At the same time, small vertical-axis wind turbines (VAWTs) have attracted interest for urban and infrastructure-integrated applications because they can accept wind from multiple directions and can be installed where horizontal-axis wind turbines are difficult to accommodate. This research paper proposes an integrated **Vertical Axis Wind-Turbine Noise Barrier (VAWT-NB)** in which small vertical-axis wind turbines are incorporated into a roadside noise-barrier structure.

The proposed system combines three functions: attenuation of traffic noise, harvesting of wind energy, and utilization of existing transportation infrastructure. The study reviews VAWT aerodynamic characteristics, traffic-noise barrier principles, turbine-generated noise, structural requirements, and suitable performance indicators. A conceptual design based primarily on a low-speed Savonius or hybrid Savonius-Darrieus rotor is proposed for locations characterized by turbulent and multidirectional wind. The acoustic performance can be assessed using barrier insertion loss, while energy performance can be evaluated using power coefficient, annual energy yield, and capacity factor. The proposed research methodology combines computational fluid dynamics (CFD), computational aeroacoustics, acoustic propagation modelling, structural analysis, and experimental validation.

The literature indicates that VAWTs can be suitable for constrained and turbulent environments, but urban wind conditions can also reduce energy performance and increase structural fatigue. Experimental research has identified blade-passing frequency and low-frequency sound as important components of VAWT noise. Therefore, the turbine must be designed so that its additional acoustic emission does not compromise the primary noise-barrier function. The proposed concept has potential applications along highways, bridges, railway corridors, urban expressways, industrial boundaries, and other transportation infrastructure.

Keywords: Vertical Axis Wind Turbine, VAWT, Noise Barrier, Highway Noise, Savonius Turbine, Urban Wind Energy, Renewable Energy, Acoustic Attenuation, Traffic Noise, Sustainable Infrastructure.

Introduction

The growth of cities, transportation networks, and industrial infrastructure has increased both electricity demand and environmental noise. Road traffic is one of the dominant sources of environmental noise in urban areas. Conventional noise barriers are commonly constructed between highways and nearby receivers to reduce the direct propagation of traffic noise. Their basic operating mechanisms include reflection, absorption, and diffraction of sound waves. Highway noise barriers commonly provide approximately 5–10 dB of noise reduction when appropriately designed, although the actual value depends strongly on barrier geometry, source-receiver arrangement, frequency, and environmental conditions. Federal Highway Administration+1

Although conventional barriers provide an effective environmental function, they generally occupy substantial roadside space without generating useful energy. This creates an opportunity to combine noise-control infrastructure with renewable-energy technology.

Vertical-axis wind turbines are particularly interesting for this purpose. Unlike conventional horizontal-axis wind turbines, the rotational axis of a VAWT is approximately perpendicular to the incoming wind direction. Consequently, many VAWT configurations can operate without an active yaw mechanism. Recent reviews identify Savonius, Darrieus/H-rotor, helical Darrieus, and hybrid configurations as important VAWT families.

A major challenge, however, is that the proposed system is intended for locations where noise reduction is itself a primary objective. A turbine that produces significant aerodynamic or mechanical noise could reduce the effectiveness or social acceptability of the barrier. Experimental research on small VAWTs in urban

environments has shown that low-frequency noise becomes increasingly important with wind speed and that blade-passing frequency is an important parameter in VAWT noise generation. ScienceDirect

Therefore, the central research question is:

Can a carefully designed vertical-axis wind turbine be integrated into a roadside noise barrier so that useful wind energy is harvested without compromising the acoustic performance of the barrier?

This paper develops a conceptual and research framework for answering this question.

Research Gap

The literature contains substantial research on:

- VAWT aerodynamic optimization
- Small wind turbines in urban environments
- VAWT acoustic emissions
- Conventional highway noise barriers

However, comparatively less research is available on the **combined optimization of VAWT energy harvesting and noise-barrier performance**.

The research gap can therefore be expressed as:

Existing studies generally optimize either the energy performance of VAWTs or the acoustic performance of barriers, whereas an integrated VAWT-noise-barrier system requires simultaneous optimization of aerodynamic, acoustic, structural and energy-performance parameters.

Important unanswered questions include:

1. How much power can be generated by a barrier-mounted VAWT?
2. How does the barrier modify the wind velocity entering the rotor?
3. Does the turbine increase noise at nearby receivers?
4. Can the turbine opening be designed without significantly reducing barrier insertion loss?
5. Which rotor—Savonius, Darrieus or hybrid—is most appropriate?
6. What rotor spacing minimizes aerodynamic interference between adjacent turbines?
7. How does vehicle-induced airflow affect energy production?
8. What is the optimum combination of turbine height and barrier height?
9. What is the lifecycle cost compared with a conventional barrier plus separately installed renewable-energy system?

Objectives

The main objective of this research is to develop and evaluate an integrated **Vertical Axis Wind-Turbine Noise Barrier** for transportation infrastructure.

Specific objectives are:

1. To design a small VAWT suitable for integration into a roadside noise barrier.
2. To investigate the aerodynamic performance of the turbine under turbulent and multidirectional wind.
3. To quantify the acoustic noise generated by the turbine.
4. To evaluate the traffic-noise attenuation of the integrated barrier.
5. To determine the optimum turbine and barrier geometry.
6. To investigate the interaction between turbine airflow and barrier acoustics.
7. To estimate annual energy generation.
8. To evaluate the structural feasibility of the proposed system.
9. To compare the proposed system with a conventional noise barrier.
10. To develop recommendations for future experimental implementation.

Proposed System Design

Recommended Configuration

For an initial prototype, a **helical Savonius or Savonius-Darrieus hybrid VAWT** is recommended.

The selection is based on:

- Low-speed operation
- Multidirectional wind acceptance
- Self-starting capability
- Relatively simple construction
- Potential suitability for turbulent environments
- Lower rotational speed compared with many lift-based systems

However, a Darrieus/H-rotor should also be evaluated as a comparison because it can provide greater aerodynamic efficiency. Recent VAWT reviews emphasize that rotor selection involves a trade-off between power coefficient, starting behavior, structural loads and noise.

. Advantages of the Proposed System

Environmental Advantages

- Reduction of traffic-noise propagation
- Renewable electricity generation
- Reduced dependence on fossil-fuel electricity
- Potential reduction in infrastructure footprint

Engineering Advantages

- Vertical-axis operation
- No active yaw mechanism for many VAWT configurations
- Modular construction
- Possibility of direct-drive generation
- Compatibility with constrained roadside spaces

Economic Advantages

- Dual-purpose infrastructure
- Potential electricity savings
- Possibility of powering local sensors and lighting
- Potential long-term lifecycle benefits

Urban Advantages

- Can be incorporated into existing transportation corridors
- Does not require a separate large wind-turbine site
- Can provide a visible sustainability feature
- Suitable for smart-city infrastructure

Limitations

The concept also has important limitations.

Low Urban Wind Speeds

Urban and roadside wind may not contain sufficient energy for high annual power production.

High Turbulence

Turbulence can reduce aerodynamic performance and increase fatigue loading. Research on built-environment wind turbines identifies turbulence and dynamic loading as significant challenges. ScienceDirect

Additional Acoustic Emissions

The turbine itself becomes a potential noise source. Poor rotor selection could reduce the acoustic benefit of the barrier.

Structural Complexity

A conventional barrier is comparatively simple, whereas the integrated system contains moving machinery and electrical equipment.

Maintenance

Bearings, generators, electrical components and rotor surfaces require inspection and maintenance.

Future Scope

Future studies should investigate:

1. CFD optimization of turbine placement on the barrier.
2. Aeroacoustic CFD modelling of blade-generated noise.
3. Experimental testing in a wind tunnel.
4. Full-scale roadside prototype testing.
5. Vehicle-induced wind energy harvesting.
6. Machine-learning-based turbine control.
7. Smart sensors for predictive maintenance.
8. Hybrid solar-PV and VAWT noise barriers.
9. Piezoelectric or other supplemental energy-harvesting technologies.
10. Modular 3D-printed turbine structures.
11. Acoustic metamaterial or perforated barrier surfaces.
12. Optimization of turbine spacing.
13. Lifecycle carbon assessment.
14. Techno-economic analysis under Indian conditions.

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