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Research Paper**Vertical Axis Wind-Turbine Noise Barrier- 1****G.G.Meshram****SHEIKH MUNEER 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.

1. 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.

2. Background

2.1 Vertical-Axis Wind Turbines

VAWTs can broadly be classified according to their aerodynamic operating principle.

2.1.1 Savonius VAWT

A Savonius turbine is primarily drag-driven. Its blades or buckets capture wind through the difference in aerodynamic drag between the advancing and returning portions of the rotor.

Their disadvantages include:

- Difficult self-starting in many configurations
- Higher rotational speed
- More complex aerodynamic loading
- Potentially higher aerodynamic noise
- Greater sensitivity to dynamic stall and cyclic loading

2.1.2 Hybrid VAWT

A hybrid rotor combines drag-driven and lift-driven mechanisms. A Savonius section can provide starting torque while a Darrieus section contributes higher efficiency at operating speed.

For a noise-barrier application, a hybrid configuration may provide a compromise between:

self-starting + low-speed operation + improved energy extraction.

3. Concept of the VAWT Noise Barrier

The proposed system consists of a continuous or semi-continuous acoustic barrier with small VAWT modules incorporated along its upper or central portion.

A conceptual arrangement is:

Roadway → Traffic noise → VAWT/solid barrier → Protected receiver

The system consists of the following major components:

1. Acoustic barrier panels
2. Vertical-axis turbine rotor
3. Vertical shaft
4. Bearings
5. Generator
6. Mechanical support frame
7. Electrical power-conditioning unit
8. Battery/grid connection
9. Acoustic treatment around the turbine module
10. Monitoring sensors

The barrier remains the primary acoustic element. The turbine modules are positioned so that the openings required for airflow do not create a direct acoustic line of sight between the roadway and the protected area.

A key design principle is therefore:

The turbine should harvest wind through controlled airflow paths while maintaining the acoustic continuity and sufficient transmission loss of the barrier.

4. Literature Review

4.1 VAWTs in Urban and Built Environments

Urban wind differs considerably from the relatively uniform wind conditions encountered by large wind turbines in open terrain. Buildings, bridges, vehicles, walls, and other structures create turbulence, separation, recirculation and rapidly changing wind direction.

A major review of small wind turbines in built environments reports that urban wind conditions generally involve lower wind speeds and higher turbulence. These conditions can produce increased dynamic loading, fatigue, and uncertainty in power output. ScienceDirect

This is important for a noise-barrier application because roadside infrastructure is itself a source of flow disturbance. The wind approaching a barrier-mounted turbine is therefore unlikely to behave like ideal free-stream wind.

The turbine design must consequently consider:

- Mean wind velocity
- Turbulence intensity
- Wind direction
- Vehicle-induced airflow
- Barrier-induced flow separation
- Gust loading
- Rotor fatigue
- Wind shear

4.2 output would depend strongly on VAWT Noise

Wind-turbine noise can originate from both mechanical and aerodynamic sources.

Mechanical sources include:

- Bearings
- Generator
- Gearbox, if used
- Shaft vibration
- Structural vibration

Aerodynamic sources include:

- Boundary-layer turbulence
- Flow separation
- Dynamic stall
- Blade-wake interaction
- Tip effects
- Blade-passing events

For small urban VAWTs, aerodynamic and low-frequency characteristics deserve particular attention. Experimental research has identified blade-passing frequency as an important parameter and has reported increasing low-frequency noise impact with increasing wind speed. [8] ScienceDirect

Recent experimental work on a small Savonius rotor also reported that noise was lowest around the maximum-power operating point at a tip-speed ratio of approximately 1.0, while sound pressure increased significantly at higher tip-speed ratios. ScienceDirect

This suggests that a noise-barrier turbine should not simply be designed for maximum rotational speed. **Acoustic performance should be included as an explicit optimization objective.**

4.3 Noise-Barrier Fundamentals

A conventional noise barrier reduces sound propagation by forcing sound waves to travel around an obstacle. The difference between the diffracted path and the direct source-receiver path is called the path-length difference.

The effectiveness of the barrier depends on:

- Barrier height
- Barrier length
- Source height
- Receiver height
- Distance from source
- Frequency
- Barrier material
- Ground characteristics
- Barrier edge geometry

Expected Results

Because the proposed VAWT-noise-barrier configuration requires physical testing, the following are **expected research outcomes rather than experimentally verified numerical results.**

The study is expected to demonstrate that:

1. A properly designed VAWT can be integrated into a roadside barrier without eliminating its acoustic function.
2. Savonius and hybrid configurations may be particularly suitable for low-speed, multidirectional and turbulent roadside wind.
3. Turbine noise will depend strongly on rotor speed and blade-passing frequency.
4. The barrier geometry will significantly affect the effective wind velocity available to the turbine.
5. Excessively high rotor speed may increase acoustic emissions and should therefore be avoided.

6. A hybrid design may provide a useful compromise between starting torque and aerodynamic efficiency.
7. The integrated system can generate useful low-power electricity for applications such as:
 - LED lighting
 - Roadside sensors
 - Traffic monitoring
 - Wireless communication
 - Environmental monitoring
 - Battery charging
 - Intelligent transportation systems
8. The system is more appropriate for distributed low-power applications than for large-scale electricity generation.

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