



INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Use Of Renewable Resources At Metro Project

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Abstract: The modern metro sector demands sustainable solutions to meet rising energy needs and reduce environmental impact. This project explores a hybrid renewable energy model by integrating solar photovoltaic panels and Vortex Bladeless wind turbines into Mumbai Metro infrastructure. A site-specific analysis reveals that installing 1,153 solar panels on a 2,306 m² station roof can generate over 3,500 kWh/day, saving ₹1 crore annually and cutting more than 1,000 tons of CO₂. To supplement this, 100 bladeless wind turbines add 100 kWh/day, offering a silent, space-efficient energy source. This hybrid system aligns with key Sustainable Development Goals (SDGs), reduces grid dependency, lowers operational costs, and presents a scalable model for green urban transport.

Keywords: Renewable Energy, Sustainable Transportation, Solar Power, Green Metro.

I INTRODUCTION

In the face of escalating climate change concerns and increasing urban energy demand, the role of public transportation in sustainable development has become more crucial than ever. Metro rail networks, known for reducing road congestion and lowering vehicular emissions, are at the forefront of eco-friendly urban mobility. However, these systems themselves consume a substantial amount of energy, particularly for station operations, lighting, ventilation, and signaling systems. With rising energy prices and growing environmental consciousness, it is essential to identify alternative energy solutions that align with both economic and ecological priorities.

India's metro systems, including Mumbai Metro, are embracing green practices to meet energy efficiency goals. Integrating renewable sources such as solar and wind power not only reduces operational costs but also significantly lowers the carbon footprint of metro projects. Metro stations, often built on elevated platforms with wide rooftops, offer ideal spaces for solar photovoltaic installations. Additionally, incorporating new-age technologies like bladeless wind turbines can further diversify the energy mix without compromising urban aesthetics or safety.

Metro projects have emerged as vital lifelines in India's urban landscape. With growing ridership and infrastructure expansion, energy consumption in metro systems is significant. To ensure sustainability, renewable energy sources are increasingly being integrated.

One such innovative solution is the Vortex Bladeless wind turbine, as shown in Figure 1. Unlike conventional turbines, it generates energy by oscillating with the wind instead of rotating blades. This reduces maintenance, noise, and hazards to wildlife. It is ideal for densely populated areas like metro stations.

Working of Vortex Bladeless Wind Turbine: The Vortex Bladeless wind turbine functions on a principle known as "vortex-induced vibration." When wind flows past a cylindrical or pole-like structure, it creates swirling patterns of air (vortices) on either side. These vortices cause the pole to shake or vibrate sideways.

The turbine is designed to take advantage of this natural movement. Inside the base of the pole, there is a generator system. As the pole vibrates back and forth due to the wind, this movement is transferred to the generator. The generator uses a system of magnets and coils to turn this motion into electrical energy.

A key part of the design is a flexible rod or mast that helps the turbine to naturally match the frequency of the wind's vortices, making it vibrate more efficiently. There are no moving parts like rotating blades, which means less wear and tear, lower noise, and very little maintenance.

This technology is especially suitable for urban areas because it is compact, safe around people and birds, and can still work even with moderate wind speeds. It does not need strong gusts to function, making it ideal for metro station rooftops or open areas around depots.

II REVIEW OF LITERATURE

1. Rooftop Solar Integration in Metro Systems

Sharma et al. (2018) studied the implementation of rooftop solar panels in the Delhi Metro, demonstrating that such systems can effectively supply a substantial portion of non-traction energy requirements, thereby reducing operational costs and emissions.

2. Feasibility in Mumbai Metro Infrastructure

Mehta and Kulkarni (2020) analyzed the potential for photovoltaic panel installations on Mumbai Metro stations. Their findings confirmed the technical and economic viability of solar energy integration, particularly for elevated stations with large roof areas.

3. Hybrid Renewable Energy Approach

Kumar et al. (2022) proposed a hybrid model combining solar and wind energy for railway applications. The study reported increased energy efficiency and enhanced sustainability, along with significant reductions in carbon emissions.

4. Bladeless Wind Turbines in Urban Settings

Singh and Patel (2021) examined the application of bladeless wind turbines in dense urban environments. Their research emphasized the turbines' silent operation, safety, and minimal space requirements, making them suitable for metro station integration.

5. National Policy Perspective

The NITI Aayog report (2021) underlined the critical role of renewable energy in transforming urban public transport. The report advocated for clean energy adoption across metro systems to help achieve India's Sustainable Development Goals (SDGs).

6. Financial Viability of Solar Energy

Mishra et al. (2019) performed a financial analysis of solar energy deployment in public transport, revealing long-term cost savings over conventional electricity use, with faster return on investment in high-exposure areas.

7. Net-Zero Metro Stations

Bhatt and Joshi (2020) introduced the concept of net-zero energy metro stations. Their study showed how combining energy-efficient technologies with renewables can create sustainable and self-sufficient transport infrastructure.

8. Potential of Small-Scale Wind Systems

An IRENA report (2022) highlighted the potential of compact wind energy systems in constrained urban environments. The report suggested these systems could complement solar power in metro and other public transit infrastructures.

9. Renewable Energy in Metro Rail Depots

Deshmukh (2021) evaluated renewable energy strategies for metro rail depots, identifying solar and small-scale wind systems as key contributors to energy optimization and reduced environmental impact.

10. Technical Advancements in Bladeless Wind Technology

Publications by Vortex Bladeless S.L. (2022) detailed the functionality, design, and advantages of bladeless turbines, supporting their integration into transport infrastructure for safe, quiet, and efficient energy generation.

III.DISCUSSIONS

This hybrid model provides consistent renewable energy, aligns with SDG 7 (Affordable and Clean Energy) and SDG 11 (Sustainable Cities), and makes metro systems more eco-friendly.

The findings from this study suggest that combining solar panels and Vortex Bladeless wind turbines can offer a reliable and clean energy source for metro infrastructure. Solar panels, due to Mumbai's high sunshine availability, can generate a significant amount of power daily, reducing dependence on grid electricity. Their installation on station rooftops not only makes use of unused space but also contributes to lower electricity bills and carbon emissions. On the other hand, Vortex Bladeless wind turbines are highly suitable for locations with space constraints or partial shading, where solar panels may not perform optimally. Their compact design, low noise, and minimal maintenance requirements make them ideal for urban public spaces like metro stations. Although each unit generates less energy than a solar panel, when deployed in groups, they provide a consistent supplementary source of renewable power.

Solar System: $1153 \text{ panels} \times 3.08 \text{ kWh} = 3551.24 \text{ kWh/day}$ Cost savings: $\text{₹}8 \times 3551.24 = \text{₹}28,409.92/\text{day}$
Annual: $\text{₹}1,02,27,571.20$; Carbon savings: 1,062 tons/year

Vortex Wind Turbines: $100 \text{ units} \times 1 \text{ kWh} = 100 \text{ kWh/day}$

Cost savings: $\text{₹}800/\text{day}$; Annual: $\text{₹}2,92,000$; Carbon savings: 30 tons/year

Total:

Energy: 3651.24 kWh/day Annual savings: $\text{₹}1,05,19,571$ Carbon reduction: 1092 tons/year

IV Conclusion

When both systems are used together, they form a hybrid setup that maximizes energy capture throughout the day and across varying weather conditions. This reduces strain on traditional power sources and ensures a stable and sustainable energy supply for metro operations. Overall, the combination of solar and bladeless wind energy technologies presents a practical and forward-looking solution for sustainable metro systems in alignment with national energy goals and the Sustainable Development Goals.

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