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# Design and Development of a Roof Turbine Ventilator Generator for Household AC Applications

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## ABSTRACT

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This study designed and evaluated a roof turbine ventilator generator intended to convert natural wind energy into usable electrical power for low-wattage household AC and DC applications. An experimental engineering approach was used to develop a vertical-axis roof ventilator mechanically coupled to an AC generator. Generated AC output was rectified to DC, regulated through a charge controller, stored in a 12 V battery, and supplied either directly to 12 V DC loads or through an inverter for 220 V AC loads. Performance was examined across reported wind speeds of 7.9, 8.9, and 9.9 mi/hr, corresponding to computed wind forces of 15.33, 19.47, and 22.72 N. Battery tests included discharge under a 3 W LED and 2.4 W exhaust fan, charging without load, and charging while a 3 W LED load was connected. Under combined discharge, battery voltage decreased from 12.90 to 12.72 V over five minutes and from 12.72 to 12.36 V over the next ten minutes. Under no-load charging, voltage increased from 12.70 to 12.72 V in five minutes and to 12.76 V after a further ten minutes. With a 3 W LED connected, voltage decreased from 12.72 to 12.33 V over five minutes and to 12.25 V over the next ten minutes. The findings demonstrate that the prototype can harvest natural airflow for low-power electrical applications, while performance remains strongly dependent on wind availability and installation location. The study recommends lighter turbine materials, higher and more open installation sites, and higher-capacity generation and power-conditioning components for future development.

**Keywords:** *roof turbine ventilator, wind energy conversion, household AC applications, renewable energy, off-grid power generation, vertical-axis wind turbine*

## INTRODUCTION

Power interruptions and increasing energy costs create practical problems for households, small businesses, and communities that depend on continuous electricity. Renewable and distributed energy technologies are therefore of interest as supplementary or backup sources. The source manuscript situates roof-mounted wind-energy systems within this broader need for continuity during grid failures and for lower-cost energy alternatives (Smith & Patel, 2023; Martinez & Lee, 2022).

Wind energy is especially attractive because it can be harvested wherever adequate airflow is available. Roof turbine ventilators normally use natural wind and buoyancy-driven airflow to ventilate indoor spaces, but the same rotational motion can be coupled to a small generator. Prior work cited in the source manuscript has explored microgeneration through roof-mounted ventilators and retrofitted micro-generators (Al-Falahi et al., 2021; Subramanian et al., 2021; Suryadi, 2020).

The engineering challenge is not limited to producing voltage. A practical system must convert rotational energy to electricity, rectify alternating current, regulate charging, store energy safely, and provide outputs compatible with DC or household AC loads. Technical reviews of wind-energy harvesting and conversion emphasize the importance of conversion and power-management stages in usable wind-energy systems (Perera et al., 2022). The source manuscript therefore integrates a rectifier, charge controller, 12 V battery, and inverter with the turbine-generator assembly.

The project also responds to efficiency and sustainability concerns. Renewable energy and energy-efficiency measures are discussed in the source references as mechanisms for reducing energy use and expenditure and for supporting sustainability goals (Amoah et al., 2022; Owusu & Asumadu-Sarkodie, 2016; Attanayake et al., 2024; Ahmed et al., 2024). Green-building literature likewise considers the integration of renewable energy technologies into buildings (Chen et al., 2023).

Accordingly, this study designed and tested a roof turbine ventilator generator for household AC and DC applications. It examined whether the system could convert available wind into electrical energy, characterized battery charging and discharging behavior under selected load conditions, and identified practical limitations and design improvements for future prototypes.

## Literature Review

### *Roof Turbine Ventilation and Building Airflow*

Roof turbine ventilators are passive or wind-assisted devices designed to remove warm indoor air while drawing replacement air through openings in the building. The source manuscript notes their role in removing heat, smoke, fumes, and humidity and in supporting indoor comfort. Related literature in the reference list addresses ventilation performance, indoor air quality, thermal comfort, and ventilation energy use (Cuce et al., 2019; Liao et al., 2021).

Wind behavior in the built environment is central to ventilator performance. Aktan (2014) examined wind ventilation in built environments, reinforcing the importance of site exposure and airflow conditions. In the present prototype, the same airflow that drives ventilation is also the mechanical input for electrical generation; therefore, lower or sheltered installation locations reduce both rotation and electrical output.

### *Roof-Mounted Wind Microgeneration*

The source references show continuing interest in combining roof turbine ventilators with electrical generators. Al-Falahi et al. (2021) examined microgeneration using roof-mounted wind turbine ventilators, while Subramanian et al. (2021) addressed green-energy harvesting through ventilators retrofitted with micro-generators. Suryadi (2020) likewise presented turbine ventilators as an alternative power-generation concept.

These systems differ from conventional large wind turbines because the available mechanical power is modest and highly dependent on local airflow. Their most realistic applications are therefore low-power loads, charging, or supplemental energy. The present study follows this small-scale approach by targeting LED lighting and a 12 V exhaust fan rather than high-demand household appliances.

Power conditioning is required because the generator output is not directly suitable for storage or household use. Watanakul (2017) explored roof-ventilator-related DC sources in inverter applications, while Perera et al. (2022) reviewed wind-energy harvesting and conversion systems. The present design similarly uses rectification, charge regulation, battery storage, and inversion as sequential energy-management stages.

### *Renewable Energy, Efficiency, and Household Application*

Renewable-energy adoption is frequently linked with sustainability, climate mitigation, and reduced dependence on conventional energy sources. The source manuscript cites broad renewable-energy literature addressing sustainability and climate change (Owusu & Asumadu-Sarkodie, 2016; Attanayake et al., 2024) and renewable-energy communities and implementation challenges (Ahmed et al., 2024).

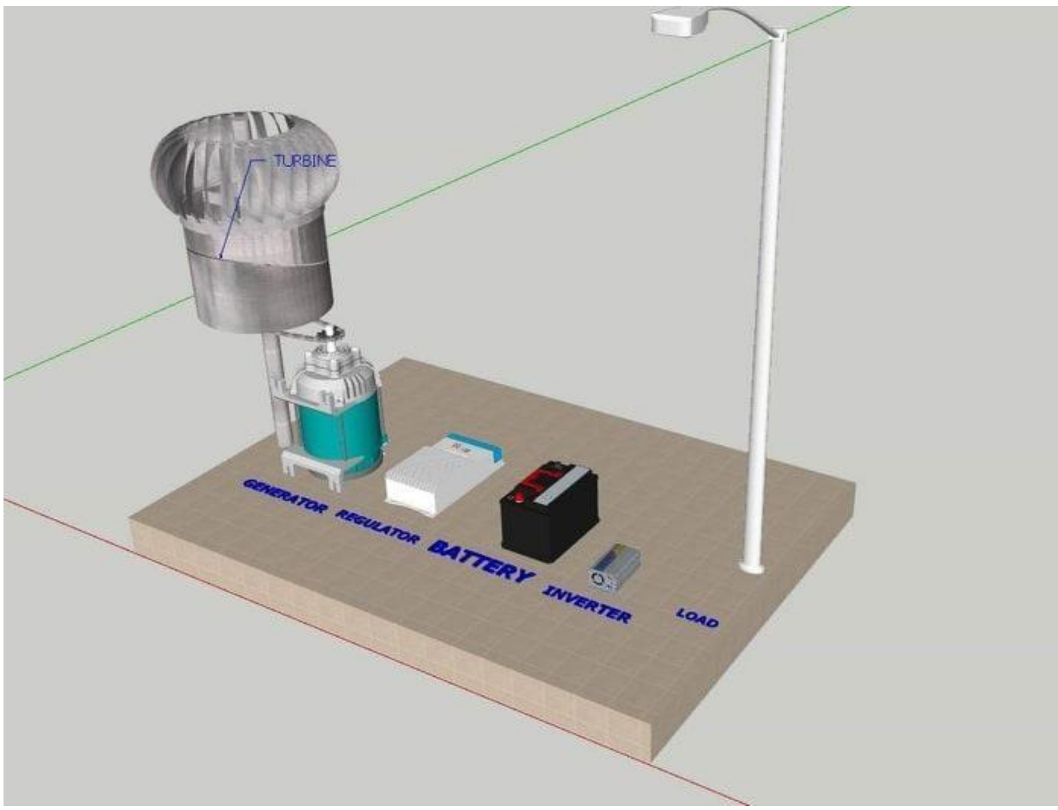
At the building scale, renewable technologies can complement energy-efficiency strategies. Amoah et al. (2022) addressed renewable energy and energy efficiency in relation to expenditure and consumption, while Chen et al. (2023) reviewed renewable-energy integration in green-building practice. These perspectives support the study's goal of developing a small supplementary power source rather than replacing the household grid.

### Engineering Design and Development Basis

The project follows an applied engineering-development orientation in which theoretical concepts are translated into a working prototype and tested under observable operating conditions. Burlacu (2022) discusses capstone work as a bridge from theory to practice, which is consistent with the design-development character of the present study.

The source manuscript identifies electromagnetic induction as the core conversion principle: wind turns the turbine and generator rotor, mechanical rotation produces electrical output, and the generated power passes through the storage and load-management stages. The proposed technical configuration is shown in Figure 1.

Figure 1. *Proposed Technical/Experimental Design*




## METHODS

### Research Design

The study used an experimental engineering design-development approach. The prototype was assembled, operated under reported wind conditions, and evaluated through direct measurements of wind-related force, battery voltage, current, charging behavior, and discharging behavior.

### Research Setting and Prototype Configuration

The project was supported by the facilities and resources of Quezon City University. The wind-speed results table in the source manuscript is identified as 'Average Wind Speed (Bulacan)'; however, the manuscript does not provide a more precise field-test address. The prototype consisted of a vertical-axis roof turbine ventilator

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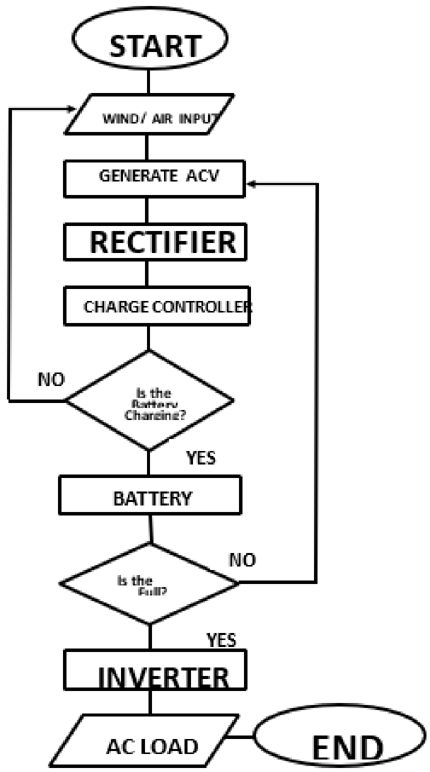
Volume 2 Issue 8 (August 2026)

mechanically connected to an AC generator, followed by a rectifier diode, charge controller, 12 V battery, inverter, and low-power AC/DC loads.

**System Operation**

Wind rotated the turbine blades and generator rotor, converting kinetic wind energy into mechanical rotation and then AC electrical output. The rectifier converted the AC output to DC before it entered the charge controller. The charge controller regulated charging and protected the battery from overcharging. Stored 12 V DC could be supplied directly to a DC exhaust fan or converted through an inverter for 220 V AC loads.

Figure 2. *System Flow Chart*




**Data Gathering and Experimental Procedure**

The source manuscript reports that technical information was gathered from consultants, library materials, journals, theses, and online sources related to power generation, wind turbines, and ventilation development. Experimental measurements were then conducted on the prototype. Wind conditions were classified as average, medium, and maximum at 7.9, 8.9, and 9.9 mi/hr. Battery behavior was measured under three test conditions: discharging with a 3 W LED and 2.4 W exhaust fan connected, charging without load, and charging while a 3 W LED load was connected.

**Computation and Data Analysis**

Wind-force values were computed in the source manuscript using air density of 1.229 kg/m³, an assumed area of 1 m², and the square of wind speed. Battery charging time was expressed as T = Ah/A, while discharge time was expressed as T = Wh/W. Experimental results were summarized descriptively using observed voltage, current, elapsed time, wind speed, and computed wind force. No inferential statistical test was reported.

**Safety and Environmental Considerations**

The prototype incorporated a charge controller to limit battery overcharging and used low-wattage test loads. The study's environmental objective was to generate electricity from natural airflow without fuel combustion or direct waste production. The source manuscript did not report human participants or animal subjects.

## RESULTS AND DISCUSSION

### Wind Speed and Computed Wind Force

Computed wind force increased as reported wind speed increased. At 7.9 mi/hr, the computed wind force was 15.33 N; at 8.9 mi/hr, it increased to 19.47 N; and at 9.9 mi/hr, it reached 22.72 N. The pattern supports the source manuscript's conclusion that the prototype performs better at higher and more exposed locations where airflow is stronger and more consistent.

Table 1. *Reported Wind Speed and Computed Wind Force*

| No. | Air Level | Air Speed (mi/hr) | Wind Force (N) |
|---|---|---|---|
| 1 | Average | 7.9 | 15.33 |
| 2 | Medium | 8.9 | 19.47 |
| 3 | Maximum | 9.9 | 22.72 |

The observed trend is consistent with the design premise that available wind determines turbine rotation and generator performance. This also explains the study's emphasis on high, open installation sites rather than sheltered ground-level locations.

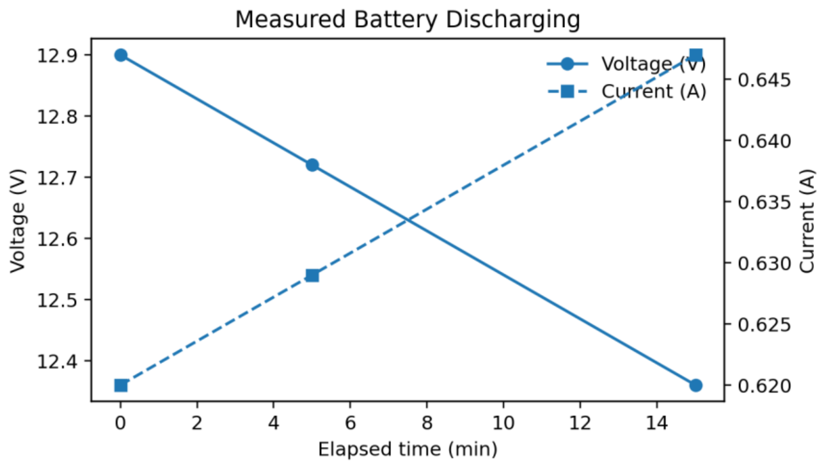
### Battery Discharging Under Combined Load

With the 3 W LED and 2.4 W exhaust fan connected, battery voltage declined over the 15-minute observation period. During the first five minutes, voltage decreased from 12.90 to 12.72 V while current increased from 0.620 to 0.629 A. Over the next ten minutes, voltage decreased further to 12.36 V while current increased to 0.647 A.

Table 2. *Measured Battery Discharging*

| Trial | Time | Minutes | Voltage (V) | Current (A) |
|---|---|---|---|---|
| 1 | 11:00 | 5 | 12.90 | 0.620 |
| | 11:05 | — | 12.72 | 0.629 |
| 2 | 11:05 | 10 | 12.72 | 0.629 |
| | 11:15 | — | 12.36 | 0.647 |

Figure 3. *Measured Battery Discharging*




The discharge test confirms that the battery could supply the selected low-wattage loads, but stored voltage decreased as energy was delivered. The result underscores the need to match load demand with battery capacity and the rate at which the wind-driven generator can replenish stored energy.

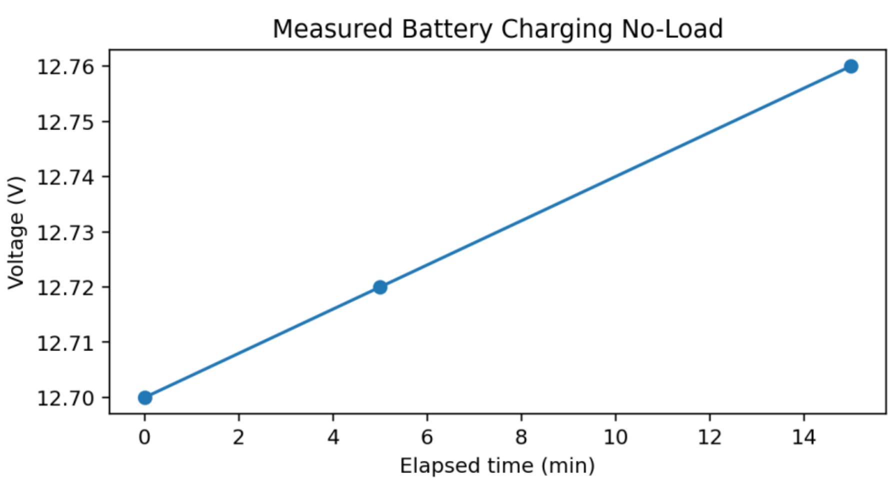
**Battery Charging Without Load**

When no load was connected, the battery voltage increased during both charging trials. Voltage rose from 12.70 to 12.72 V in the first five minutes and from 12.72 to 12.76 V over the next ten minutes. The source manuscript reports voltage gains of 0.02 V and 0.04 V for the two intervals, respectively.

Table 3. *Measured Battery Charging No-Load*

| Trial | Time | Minutes | Voltage (V) |
|---|---|---|---|
| 1 | 11:15 a.m. | 5 | 12.70 |
| | 11:20 a.m. | — | 12.72 |
| 2 | 11:20 a.m. | 10 | 12.72 |
| | 11:30 a.m. | — | 12.76 |

Figure 4. *Measured Battery Charging No-Load*



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The positive voltage change under no-load conditions provides direct evidence that the turbine-generator and charging circuit were able to deliver net energy to the battery during the observation period. The small magnitude of the increase is consistent with the source manuscript's conclusion that the prototype is suitable for low-power or supplementary applications rather than high-demand household loads.

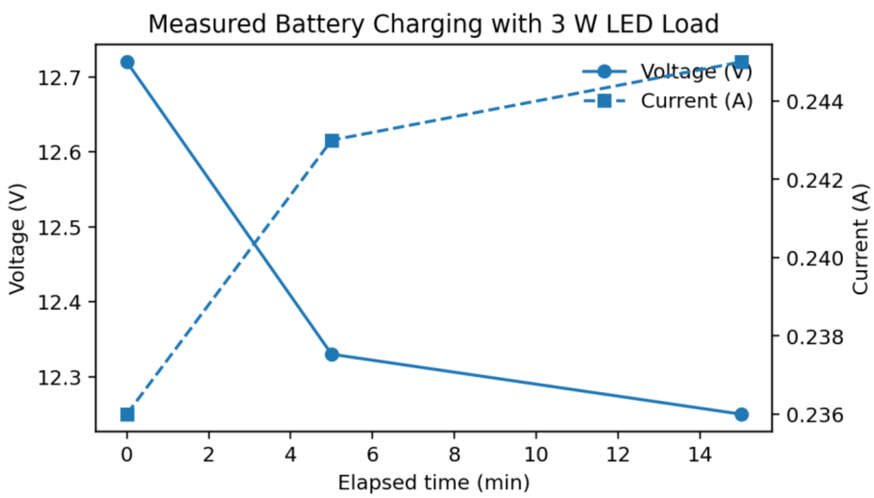
**Battery Behavior While Charging with a 3 W LED Load**

When a 3 W LED load remained connected during charging, battery voltage declined rather than increased. It decreased from 12.72 to 12.33 V during the first five-minute interval and from 12.33 to 12.25 V during the next ten minutes. Current increased slightly from 0.236 to 0.243 A and then to 0.245 A.

Table 4. *Measured Battery Charging with 3 W LED Load*

| Trial | Time | Minutes | Voltage (V) | Current (A) |
|---|---|---|---|---|
| 1 | 11:30 a.m. | 5 | 12.72 | 0.236 |
| | 11:35 a.m. | — | 12.33 | 0.243 |
| 2 | 11:35 a.m. | 10 | 12.33 | 0.243 |
| | 11:45 a.m. | — | 12.25 | 0.245 |

Figure 5. *Measured Battery Charging with 3 W LED Load*




Because battery voltage declined while the LED remained connected, the measured charging input under those conditions did not fully offset the simultaneous load demand during the observation window. This result reinforces the importance of greater wind input, reduced rotational resistance, and higher-capacity generation components if the system is to support loads continuously while also restoring battery charge.

**Overall Prototype Performance**

Taken together, the tests show that the prototype can convert natural airflow into stored or directly usable electrical energy for low-wattage applications. Performance was sensitive to wind conditions and load state. The no-load test produced a measurable increase in battery voltage, whereas the connected-load test produced a net decrease. The practical implication is that the roof ventilator generator functions most effectively as a supplementary or off-grid low-power source when installed in an exposed location with sustained airflow.

## CONCLUSION

The developed roof turbine ventilator generator demonstrated the feasibility of using natural airflow to produce electricity for selected low-power household AC and DC applications. Wind speed was directly associated with the computed wind force acting on the turbine, and the prototype successfully produced charging behavior under no-load conditions. The battery also supplied the selected LED and exhaust-fan loads, although voltage decreased during discharge.

The experiment further showed that available generation was insufficient to increase battery voltage while a 3 W LED remained connected during the measured charging intervals. System performance therefore depends strongly on wind availability, installation exposure, rotational resistance, generator capacity, battery capacity, and connected load. The prototype is best regarded as a low-power supplementary energy system rather than a replacement for conventional household electrical supply.

### Recommendation

Use lighter turbine materials and lower-resistance mechanical connections to improve rotational response and energy-conversion efficiency.

Install the prototype in high, open, naturally windy locations where airflow is stronger and more consistent.

Evaluate higher-capacity generators, improved charge-control electronics, and more efficient power-conditioning components to increase usable output.

Conduct longer-duration field tests across different wind conditions and load profiles to establish charging rates, energy yield, battery cycling behavior, and practical operating limits.

Future versions should compare alternative turbine sizes, generator ratings, storage capacities, and AC/DC load combinations while retaining appropriate electrical protection and safety controls.

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