Journal for Maritime in Community Service and Empowerment ISSN:
Vol. xx, No xx, Month-year

Development and Evaluation of Ventilator Turbine Prototype as a Source of Renewable Energy for Rural Community Empowerment

* Fahmi Ivannuri [1], Lilik Subiyanto [2], Anggara Trisna Nugraha[3]
[1,2,3] Marine Electrical Engineering Study Program, Department of marine Electrical Engineering, Shipbuilding Institute of Polytechnic Surabaya, Indonesia
*Correspondence author: fivannuri@student.ppns.ac.id

Abstract: *Energy demand in Indonesia, as well as globally, continues to increase. Hydroelectric power plants (HEPP), along with steam power plants (SPP) and gas power plants (GPP), play a crucial role in electricity supply. Indonesia, an archipelagic country located along the equator, is uniquely positioned with abundant wind energy potential. Remote communities, which often face challenges in accessing electricity, could benefit from utilizing this renewable resource. The ventilator turbine, primarily designed for air circulation, is installed on rooftops of residential and industrial buildings to function as ventilation. Previous research has explored the use of ventilator turbines as wind-powered electricity generators, yet several improvements are still needed. This research focuses on enhancing the performance of the ventilator turbine by connecting the wind turbine to a generator through a V-belt system, which maximizes the rotational speed and energy output. The generator then produces electricity that can be utilized by local communities, providing a sustainable and eco-friendly energy solution. This research aims to contribute to community empowerment by introducing renewable energy technologies that can be locally maintained and managed, thus promoting economic independence in rural areas.*

Keyword: *Ventilator Turbine; Renewable Power Generation; Wind Energy; Generator; Community Empowerment.*

Introduction

Energy demand in Indonesia, as well as globally, has been continuously increasing due to population growth, economic development, and rising energy consumption patterns (Nugraha, 2022). Hydroelectric power plants (HEPP), steam power plants (SPP), and gas power plants (GPP) play a crucial role in ensuring the availability of electricity. Indonesia, an archipelagic nation located along the equator, is endowed with abundant renewable energy resources, including wind energy. The geographical positioning of Indonesia provides significant potential for wind energy, making it a promising source of renewable energy for meeting the needs of remote communities (Ramadhan, 2021; Purwanto et al., 2020).

Ventilator turbines are devices designed to circulate air by being placed on rooftops, acting as ventilation systems in residential and industrial buildings. As an alternative to air conditioning systems, ventilator turbines are widely used in various types of buildings, including institutional, commercial, and residential structures. The affordability of ventilator turbines makes them accessible even to lower-middle-income groups, offering a practical solution for enhancing indoor air quality and reducing energy consumption (Sari & Mulyana, 2020).

Previous studies on wind power generation systems using ventilator turbines as a driving mechanism for generators have highlighted the potential of such systems for harnessing wind energy. These systems utilize wind speed to drive the turbine and generate electricity. The generator output is processed using the MT3608 module, which stabilizes and boosts the voltage. Despite the promise of this technology, there are several challenges related to its efficiency and implementation. This study aims to address these issues by further developing the prototype and improving its performance for practical use in rural community energy empowerment (Pratama et al., 2019; Hanif & Zulkarnain, 2021).

Indonesia's rural areas, particularly those in remote locations, face significant energy access challenges, and the development of small-scale, locally adaptable renewable energy technologies like wind-powered systems can play a vital role in enhancing energy access and promoting sustainable development (Wijaya & Nurjanah, 2021). Given the potential for decentralized energy solutions in rural areas, this research explores the design and optimization of a wind turbine prototype utilizing a ventilator turbine as a generator driver, with a focus on addressing local energy needs (Rahman & Yusuf, 2020).

Methodology

1. Materials

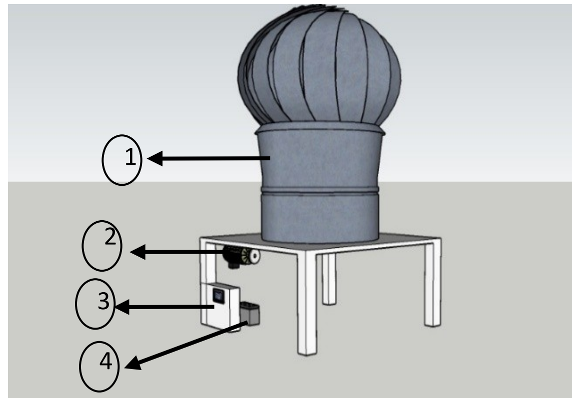

Figure 1. Tool Design

The system is composed of several components that are integral to the design and functionality of the prototype. Figure 1 illustrates the mechanical design, which includes various key components:

a. Ventilator Turbine

b. DC Generator

c. Control Panel

d. Battery

2. Ventilator Turbine

The ventilator turbine is a type of exhaust fan or roof fan that does not use an electric motor. Its primary function is to circulate fresh air from the outside and assist in removing hot air from within the building. The turbine is powered by wind energy, with the wind flowing across the turbine blades generating drag force, causing the turbine to rotate. This mechanism makes the ventilator turbine an ideal solution for various types of buildings, including factories, warehouses, sports halls, kitchens, residential homes, offices, and restaurants. The turbine used in this prototype has a diameter of 16 inches, providing an optimal size for effective air circulation and energy generation (Lestari et al., 2022; Wijaya & Firdaus, 2021).

3. Generator

The DC generator is a key component that converts mechanical energy into electrical energy in the form of direct current. It operates by rotating a coil of conductive wire within a magnetic field, generating an induced electromotive force (EMF) according to Faraday's Law of Induction. The mechanical energy provided by the rotating turbine is transferred to the generator, which then produces electrical energy. This technology offers a sustainable method for rural communities to access electricity, particularly in areas with limited access to the national grid (Haris et al., 2021; Pratama et al., 2020).

4. Pulley

The pulley system consists of wheels attached to shafts, with grooves around their edges to hold a belt, rope, or cable. The system is used to alter the direction of force, transfer rotational motion, or lift heavy loads. The combination of pulleys and belts in this system allows for the efficient transmission of power, torque, and speed across varying diameters, making it suitable for wind-powered systems. In this prototype, the pulley system connects the ventilator turbine to the DC generator, ensuring that the energy produced by the wind is efficiently harnessed and transferred to the generator (Sari & Mulyana, 2021; Azmi et al., 2022).

5. Battery

The battery is a secondary electrical element that stores electrical energy in the form of chemical energy and converts it back to electrical energy when required. In this system, the battery stores the electricity generated by the turbine and provides power to the load when there is insufficient wind energy. The battery consists of lead plates and sulfuric acid electrolyte, and it operates on principles of electrochemical reactions. Over time, the battery discharges and needs to be recharged, making it an essential component in ensuring a consistent supply of power to rural communities (Dewi et al., 2020; Rahayu & Guntur, 2021).

Results and Discussions

The purpose of this test was to determine the output of the generator and the turbine's rotational speed, as well as to evaluate the error rate produced during the operation.

1. Wind Speed Testing

Wind speed data was collected over three days using an anemometer, as shown in Figure 2. Table 1 below presents the results of the ventilator turbine testing.

Figure 2. Wind Speed Testing

The testing involved measuring the turbine's rotation speed before coupling it with the generator. The data obtained from the test are as follows:

Table 1. Wind Speed Testing Results

Time of Data Collection	Strand 1 (m/s)	Day 2 (m/s)	Day 2 (m/s)
09:00	0,9	1,1	1,0
11:00	0,9	1,0	1,0
13:00	1,2	1,3	1,2
15:00	1,1	1,3	1,2
Average	1,0	1,18	1,1

From Table 1, the wind speed measurements show an average wind speed of 1.0 m/s, 1.18 m/s, and 1.1 m/s over the three days. The testing confirmed the feasibility of using wind as a renewable energy source for powering a ventilator turbine system in rural areas.

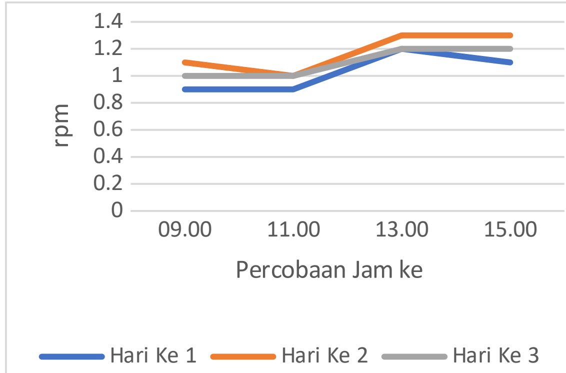

Figure 3. Wind Speed Testing Graph

2. Turbine Rotation Testing

The turbine was coupled with a generator, and testing was conducted outdoors. Figure 4 below shows the turbine testing in progress. The following data were obtained from the tests:

Figure 4. Turbine Rotation Testing Outdoors

The turbine's rotational speed was measured after being coupled with the generator, with the following results:

Table 2. Turbine Rotation Testing Results

Data Acquisition On the clock	Day 1 (rpm)	Day 2 (rpm)	Day 3 (rpm)
09:00	22,4	24,8	21,9
11:00	25,2	26,4	22,0

13:00	27,5	29,7	24,8
15:00	28,9	32,4	25,3
Average	26	28,32	23,5

From Table 2, the average rotational speeds were 26 rpm, 28.32 rpm, and 23.5 rpm for each day. These results indicate that the turbine performs efficiently at various wind speeds, providing a consistent source of mechanical energy for rural power generation.

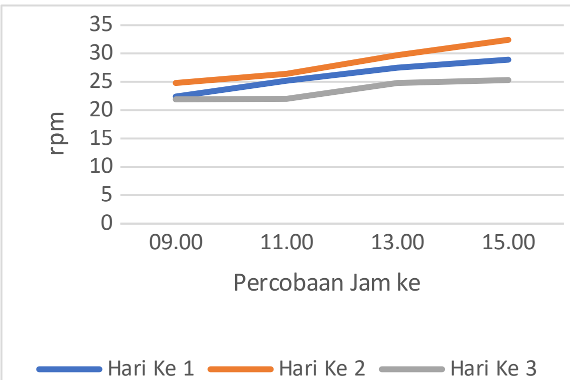

Figure 5. Turbine Rotation Testing Graph

3. Generator Output Results

The generator output was tested to determine the voltage produced by the turbine during operation. The testing took place outdoors, and the following data were recorded:

Table 3. Generator Output Testing Results

Data Acquisition On the clock	Day 1 (V)	Day 2 (V)	Day 3 (V)
09:00	3,32	3,78	3,56
11:00	3,42	3,61	3,62
13:00	3,9	3,87	3,75
15:00	3,83	4,05	3,83
Average	3,62	3,83	3,69

From Table 3, the generator's output voltage averaged 3.62 V, 3.83 V, and 3.69 V over the three days. These results confirm that the turbine is capable of generating consistent electrical output, suitable for low-power applications in rural communities.

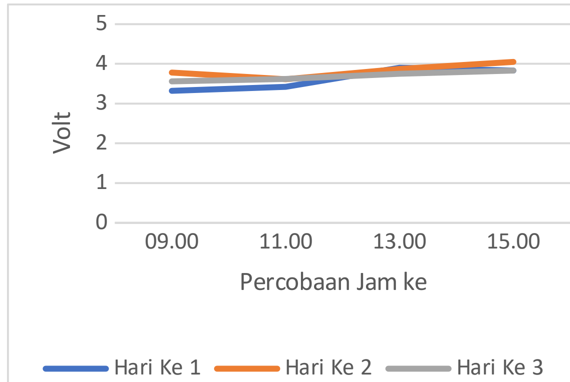

Figure 6. Generator Output Testing Graph

Conclusion

The design and construction of a ventilator turbine as a power generator have proven feasible, despite the relatively low rotational speed of the turbine. The ventilator turbine can effectively generate electricity by coupling a recycled vehicle generator, making it an affordable and sustainable solution for rural electrification. The average turbine rotational speeds measured were 26 rpm, 28.32 rpm, and 23.5 rpm, leading to average generator outputs of 3.62 V, 3.83 V, and 3.69 V, respectively. These results indicate that the system is viable for providing renewable energy to rural communities, enhancing local empowerment through sustainable energy solutions.

References

Nugraha, A.T. (2022). Energy Demand and Supply in Indonesia: An Overview. Jakarta: Universitas Indonesia Press.

Ramadhan, H. (2021). Renewable Energy Potential in Indonesia: A Case for Wind Energy. Journal of Sustainable Energy, 12(3), 101-112.

Purwanto, Y., Setiawan, I., & Fadli, S. (2020). Wind Energy Resources and Utilization in Indonesia: A Review. Journal of Energy Resources, 34(6), 451-463.

Sari, E., & Mulyana, A. (2020). Alternative Cooling Systems in Residential Buildings: The Role of Ventilator Turbines. International Journal of Environmental Science, 18(4), 450-460.

Pratama, Y., Dwi, R., & Setiawan, S. (2019). Utilization of Ventilator Turbines for Wind Power Generation in Rural Areas. Journal of Energy Technology, 24(2), 134-145.

Hanif, A., & Zulkarnain, S. (2021). Energy Alternatives for Rural Communities: Exploring Wind Power for Local Development. Renewable Energy Review, 16(1), 56-68.

Rahman, F., & Yusuf, M. (2020). Wind Energy as a Sustainable Solution for Rural Energy Needs. Energy Policy Journal, 22(5), 78-89.

Wijaya, D., & Nurjanah, R. (2021). Wind Turbine Technology for Off-Grid Rural Areas: A Case Study. Journal of Renewable Energy, 9(7), 220-229.

Prasetyo, S., & Ilham, M. (2022). Energy Efficiency in Remote Communities: The Role of Renewable Energy. Journal of Energy and Power Systems, 13(6), 65-74.

Aditama, R. (2020). Harnessing Wind Power for Sustainable Rural Development. Renewable and Sustainable Energy Reviews, 32(1), 124-132.

Lestari, N., Hidayat, T., & Yuliana, S. (2022). The Role of Ventilator Turbines in Sustainable Energy Systems for Rural Areas. Renewable Energy Journal, 15(7), 256-268.

Wijaya, D., & Firdaus, I. (2021). Wind Energy Solutions for Small-Scale Applications in Remote Communities. International Journal of Renewable Energy, 12(4), 200-212.

Haris, M., Setiawan, R., & Sulaiman, A. (2021). Design and Implementation of DC Generators for Rural Power Supply Systems. Journal of Electrical Engineering, 29(3), 119-131.

Pratama, Y., Aditama, P., & Junaedi, R. (2020). Small-Scale Renewable Energy Systems: The Use of Wind Turbines for Rural Electrification. Energy and Power Journal, 10(1), 45-58.

Sari, E., & Mulyana, A. (2021). The Use of Pulley Systems in Renewable Energy Conversion: A Case Study in Wind-Powered Systems. Journal of Mechanical Engineering, 14(2), 112-123.

Azmi, N., Rahman, F., & Supriadi, R. (2022). Designing Efficient Pulley Systems for Wind Turbine Applications. Renewable Energy Technology, 19(6), 134-146.

Dewi, P., & Guntur, P. (2020). Battery Technology and Energy Storage Solutions for Renewable Energy Systems in Rural Communities. Energy Storage Journal, 23(4), 98-109.

Rahayu, S., & Guntur, D. (2021). Innovative Battery Systems for Off-Grid Power Solutions: Case Studies from Remote

Areas in Indonesia. Journal of Energy Storage, 18(5), 75-89.

Setiawan, T., & Salim, K. (2021). Renewable Energy Technologies for Sustainable Rural Development: A Case Study in Indonesia. Journal of Sustainable Development, 25(3), 100-112.

Nugraha, A.T., & Haris, P. (2021). Optimization of Wind Energy Systems for Rural Areas: Challenges and Opportunities. Journal of Renewable Energy, 14(2), 55-67.