

# The influence of water velocity and blade number variation on the performance of water vortex turbines



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**Abstract** The growing demand for sustainable and renewable energy sources has fueled increasing interest in harnessing water energy as a viable solution for power generation. However, traditional hydropower turbines face significant challenges related to both efficiency and environmental impact. The design and fabrication of turbine blades play a crucial role in determining the efficiency and overall performance of Hydro Water Vortex turbines. This dissertation was undertaken with the primary objective of exploring the design of Water Vortex turbines. Water vortex turbines offer a promising solution by utilizing the kinetic energy of water vortices, providing higher efficiency and a lower environmental impact compared to conventional turbines. This study examines the relationship between water velocity, the number of turbine blades, and output performance, including turbine speed and output voltage (Vdc) in Hydro Water Vortex turbines. Experiments were conducted using four turbine configurations with 3, 4, 5, and 6 blades under two valve opening conditions (100% and 75%). The results demonstrated a positive linear relationship between water velocity and output voltage across all configurations. Increasing the number of blades enhanced the efficiency of converting water's kinetic energy into electrical energy, with the 6-blade configuration achieving the highest performance. At 100% valve opening, the 6-blade turbine generated a maximum voltage of 29 Vdc at a water velocity of 1.46 m/s. Meanwhile, at 75% valve opening, the highest recorded voltage was 21.06 Vdc at a water velocity of 0.74 m/s. This research confirms that both the number of blades and water velocity are critical parameters for optimizing the performance of Hydro Water Vortex turbines. Configurations with more blades are recommended for high water flow conditions to maximize energy efficiency, while fewer blades are better suited for low flow conditions. These findings contribute to the advancement of Hydro Water Vortex turbines as an efficient renewable energy solution.

**Keywords:** vortex hydro turbine, water velocity, voltage, number of blades, renewable energy

## 1. Introduction

The growing demand for sustainable and renewable energy sources has sparked increasing interest in the utilization of water energy as a potential solution for power generation. In this context, traditional hydropower turbines face significant challenges in terms of both efficiency and environmental impact. High construction costs, as well as suboptimal performance under varying water flow rates, are key obstacles that must be addressed to meet sustainability demands (Husaini, et al., 2021 and Strielkowski et al., 2021). The design and fabrication of turbine blades play crucial roles in determining the efficiency and overall performance of hydrowater vortex turbines (Alfeuz et al., 2024). By addressing the complexities of challenges such as material selection, structural integrity, and manufacturing processes, it is possible to develop hydrowater vortex turbines capable of maximizing energy extraction potential while maintaining optimal durability. This research provides an opportunity to offer concrete solutions to these obstacles while contributing to the advancement of cutting-edge technology in the fabrication of hydrowater vortex turbine blades.

Water energy is an abundant natural resource that can be utilized as a clean and sustainable solution for power generation. Although hydropower turbines have long been a conventional method for converting water energy into electricity, challenges such as high construction costs and environmental impact have driven the need for innovation (Dincer and Acar, 2015). With advancements in technology, hydro water vortex turbines have emerged as promising alternatives, offering the potential to increase energy extraction efficiency and reduce negative environmental impacts (Rehman, et al., 2023).

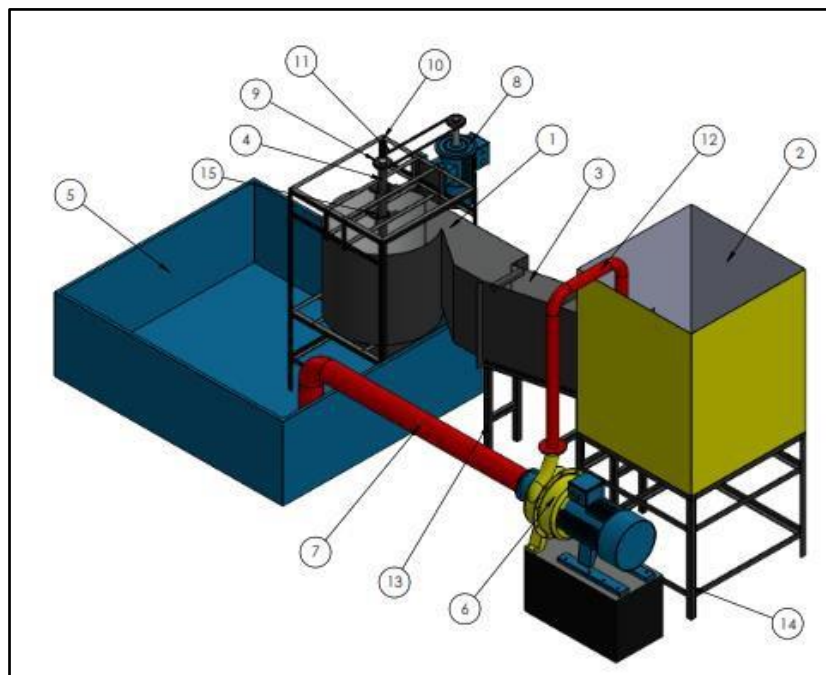


Traditional hydropower turbines face limitations such as high construction costs and often undesirable environmental impacts. Large-scale water management and dam construction require significant financial investment and frequently result in alterations to river ecosystems, which can be detrimental to the surrounding environment (Beck et al., 2012). The turbine efficiency is also a major concern, particularly when dealing with variations in water flow that occur over time. As a result, the emergence of new technologies such as hydro water vortex turbines offers an appealing alternative with the potential to overcome these challenges (Jain and Patel, 2014). Conventional turbines often exhibit suboptimal performance under variable flow rates, leading to energy waste and negative impacts on river ecosystems (Rosińska et al., 2024). Addressing the challenges of efficiency and environmental impact posed by conventional turbines, it is important to recognize that hydrowater vortex turbines have the potential to be a superior solution. Higher efficiency can be achieved by utilizing naturally rotating water vortices, thereby reducing energy losses commonly experienced with traditional turbines. In this way, water vortex turbines not only have the potential to enhance power generation performance but also mitigate the environmental issues associated with the electricity generation process (Domfeh et al., 2020).

This study aimed to explore the design of hydro water vortex turbines. The concept of water vortex turbines is promising, as they harness the kinetic energy of water vortices, offering higher efficiency and lower environmental impact than conventional turbines do. Understanding and optimizing the design of these turbines is expected to provide solutions to the previously identified challenges. This research aims to provide a deeper understanding of the performance of hydro water vortex turbines from an experimental perspective, considering various factors that can influence their efficiency. Significant contributions are expected in terms of the development of designs that can be optimized to achieve maximum energy extraction. The results of this study could serve as a foundation for further development in harnessing hydrowater vortex turbine technology as an integral part of the renewable energy portfolio. Thus, this research aims to provide concrete solutions to the need for sustainable and efficient energy, which is a major challenge in the modern era.

## 2. Materials and methods

The methodology of this research involves a comprehensive experimental approach, starting with experiments on the performance of hydrowater vortex turbines in the laboratory (Figure 1). Experimental data collection includes measurements of parameters such as rotational speed and output power under various experimental conditions.



**Figure 1** Design of the water vortex turbine.

Figure 1 Descriptions: 1) Turbine casing; 2) water drum; 3) channel; 4) turbine blade; 5) reservoir; 6) water pump; 7) water pipe; 8) generator; 9) Pulley; 10) turbine frame; 11) belt; 12) water pipe; 13) channel frame; and 14) water drum bearing frame.

The dependent variables are those that are the primary focus of the researcher. By analyzing the dependent variables, it is hoped that answers and solutions to the problems can be found. The dependent variables in this study are the generator output voltage and turbine speed. The independent variables are those that influence the dependent variables. The independent variables in this study are the number of blades used, which are 3, 4, 5, and 6 blades; the water velocity, which is

determined by the valve opening of the tank with variations of 100% and 75%; and the measurements, which are taken via the Flowatch JDC FL-03 device.

The equipment and materials used in this study include the following: a cylinder basin, the main container where the water vortex is formed to rotate the turbine. The diameter of the outlet affects the water flow rate and vortex speed. Turbine, which is the rotating part that converts the kinetic energy of water into mechanical energy. The generator is connected to the turbine to generate electricity from mechanical energy. Turbine materials, which are the materials used to make turbines, must be resistant to corrosion and have good mechanical strength. The control system is used to regulate the operation of the turbine and ensure safety. A braking system is used to stop or reduce the turbine's speed when necessary.

The stages involved in the design process of the components of the hydrowater vortex gravity turbine model include the dimensions of the channel, such as the length, width, and angles of the intake and outflow sections, which are crucial for creating the vortex needed to drive the turbine. The design also takes into account the shape of the basin, which is often conical, and the turbine runner with its blades.

Determining the shape and dimensions of the circulation tank for a water vortex turbine model is a critical aspect of its design. The geometry of the tank directly affects the formation and stability of the vortex, which is essential for turbine operation. For water vortex turbines, the circulation tank typically has a circular or conical shape to facilitate the natural formation of the vortex. The tank dimensions, such as diameter and depth, are determined on the basis of the desired flow rate, water head, and specific energy conversion requirements.

The size of the blades affects their interaction with the water flow and the torque generated. The dimensions must be optimized to ensure efficient energy transfer from the water vortex to the turbine. This impacts the smooth operation of the turbine and its ability to maintain a consistent rotational speed. Too few blades can result in jerky motion, whereas too many blades can cause excessive drag. The shape of the blades determines how effectively they can harness the kinetic energy of the water. Curved or bent blades can enhance performance by maintaining a better angle of attack during rotation.

### 3. Results

The experiments were conducted on a Micro Hydro Power Plant (PLTMH) prototype with 4 blade variations: 3, 4, 5, and 6 blades. The experimental parameters include valve opening, channel width, wet height, water velocity, turbine rotational speed, and voltage. For each blade variation, 5 experimental trials were conducted. The average values from the test results can be seen in Table 1.

The data analysis results in Table 1 show that valve opening has a significant effect on turbine performance parameters. In all the blade configurations, the water velocity, turbine RPM, and output voltage (Vdc) increased as the number of valve openings increased from 75% to 100%. The increase in water velocity is due to the higher water flow rate, which generates more kinetic energy, whereas the increased RPM and voltage reflect better energy conversion efficiency at the maximum opening. The wet height also slightly increased at 100% valve opening but remained relatively stable compared with the other parameters.

**Table 1** Experimental data for valve opening, velocity, RPM, and voltage.

Blade	Valve (%)	Water Velocity (m/s)	RPM	Voltage (Vdc)	Wet Height (cm)
3 Blade	100	1.38	433	25.46	2.48
	75	0.73	228	19.14	1.08
4 Blade	100	1.44	476,6	27.32	2.44
	75	0.75	247,2	19.34	1.14
5 Blade	100	1.44	701,2	28.28	2.62
	75	0.72	279,4	22.22	1.16
6 Blade	100	1.46	778,8	29	2.56
	75	0.74	237,6	21.06	1.16

The number of turbine blades also affects performance. More blades, such as the 5- or 6-blade configurations, resulted in higher RPMs and voltages than the 3- or 4-blade configurations did. This suggests that additional blades improve the effectiveness of capturing kinetic energy from the water flow. The 6-blade configuration generated the highest voltage and RPM at the 100% valve opening, making it the most efficient configuration for maximizing energy production. Conversely, the 3-blade configuration delivered the lowest performance and may be more suitable for applications with lower power requirements or limited water flow.

The stable wet height across all the blade variations indicates that changes in the number of blades do not significantly affect the physical conditions of the water flow. This suggests that turbine design can focus more on optimizing the RPM and voltage to enhance efficiency. Overall, for high-power applications, the 6-blade configuration with 100% valve opening is the best. However, for operational conditions with limited water flow or lower power needs, 3- or 4-blade configurations may be

an efficient choice. Further development is recommended to measure the output power efficiency on the basis of varying water flow rates and to include current analysis for total power calculations.

3.1. Influence of the Number of Blades on Turbine Rotation

Figure 2 presents the relationship between the number of blades and the turbine's rotational speed (RPM) based on valve openings for blade sizes of 3, 4, 5, and 6. The experiments are conducted for each valve opening variation at 100% and 75%.

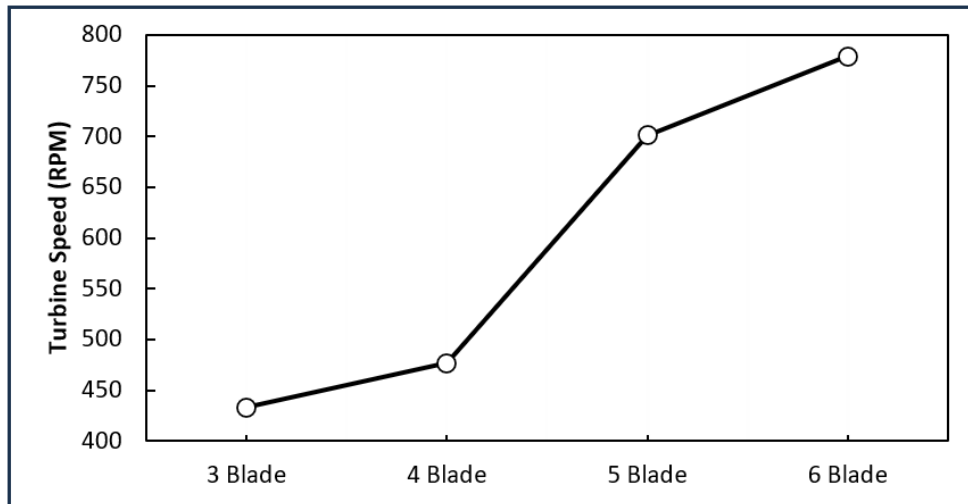


Figure 2 Influence of the number of blades on turbine rotation at 100% valve opening.

On the basis of the experimental data in Figure 2, the turbine's rotational speed (RPM) increases with the number of blades. A turbine with 3 blades achieves a rotational speed of 433 RPM, whereas a turbine with 6 blades reaches a speed of 778.8 RPM. This trend indicates that increasing the number of blades enhances the turbine's efficiency in converting fluid energy into rotational motion. With the valve fully open at 100%, the turbine can maximize the utilization of water flow, suggesting that the rotational speed is directly proportional to the number of blades.

The experimental data in Figure 3 show that when the number of valve openings is reduced to 75%, the turbine's rotational speed is generally lower than that at 100% valve opening. A turbine with 3 blades achieves a speed of 228 RPM, whereas one with 6 blades reaches 279.4 RPM. Although the speed decreases compared with that of a full opening, the trend of increasing speed with increasing number of blades remains consistent. This finding indicates that even with a reduced water flow capacity, a greater number of blades still provides aerodynamic advantages.

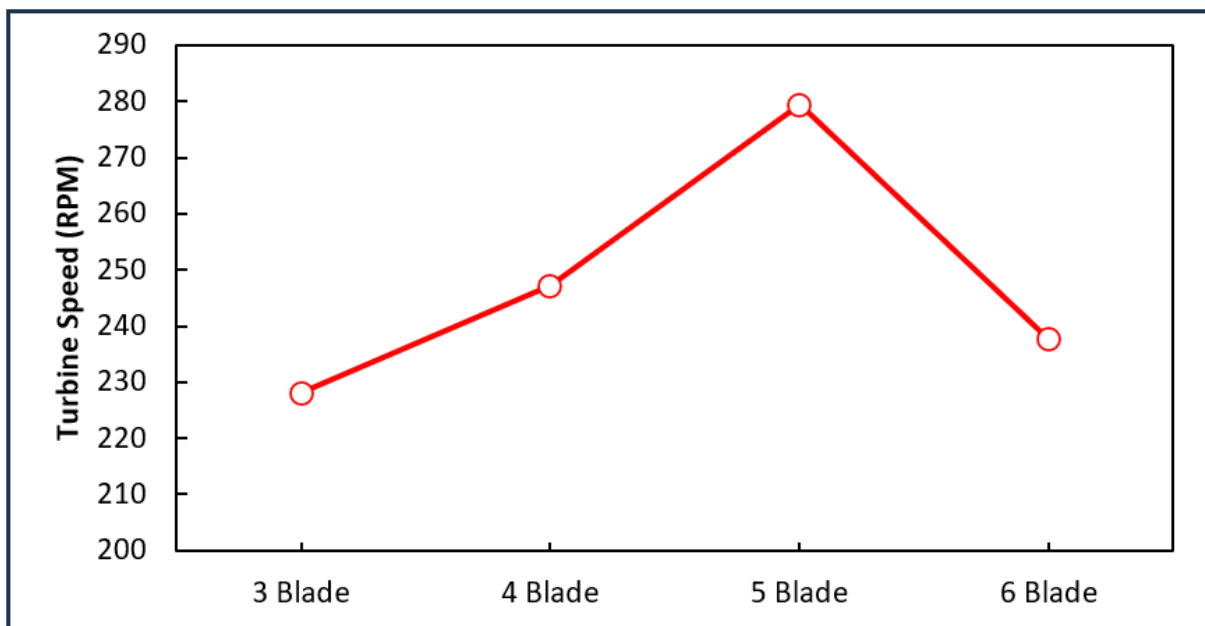


Figure 3 Influence of the number of blades on turbine rotation at 75% valve opening.

### 3.2. Influence of the Number of Blades on the Generator Output Voltage

Figure 4 illustrates the relationship between the number of blades and the voltage (Vdc) generated by the turbine, which is based on valve openings for blade variations of 3, 4, 5, and 6. The testing is conducted for each valve opening variation at 100% and 75%.

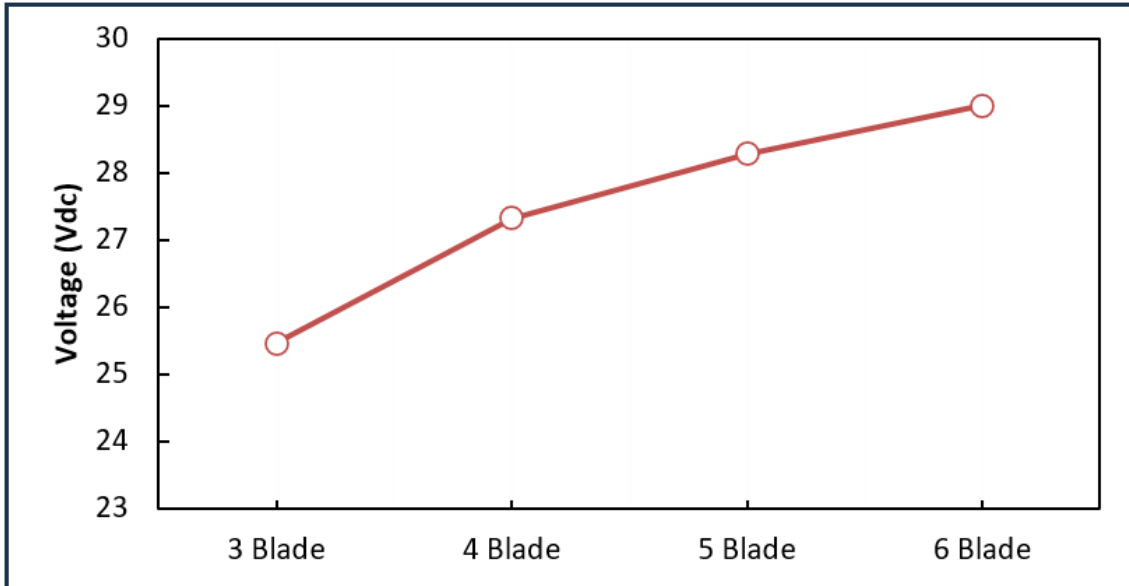


Figure 4 Influence of the number of blades on the generator output voltage at 100% valve opening.

On the basis of the experimental data presented in Figure 4, the generator's output voltage clearly increases with the number of blades. With three blades, the recorded voltage was 25.46 Vdc, which increased to 29 Vdc with six blades. Increasing the number of blades enhances the turbine's ability to achieve more stable and efficient rotation, directly contributing to a higher generator output voltage. A 100% valve opening allows for optimal utilization of the water flow, resulting in a significant difference in the output voltage across the blade variations.

The data presented in Figure 5 show the results of testing at a 75% valve opening, where the trend of increasing output voltage remains apparent, although at lower values than those of the full valve opening. The voltage for three blades is 19.14 Vdc, whereas for six blades, it reaches 22.22 Vdc. This decrease in voltage is due to the reduced water flow at the opening of the smaller valve. However, a greater number of blades still compensate for the reduced flow by improving the turbine's rotational efficiency.

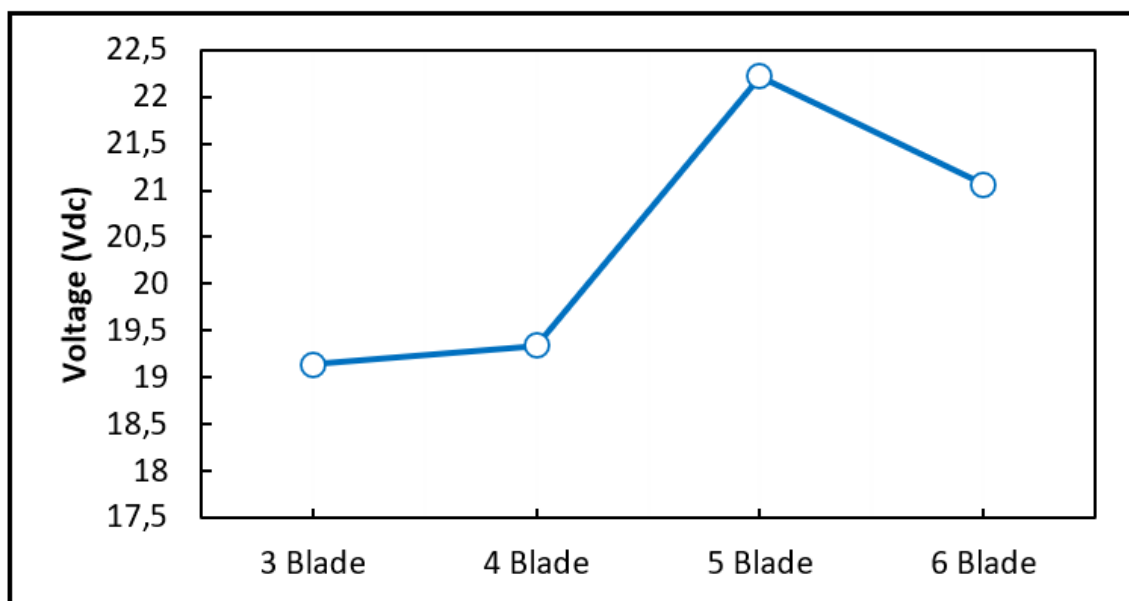


Figure 5 Effect of the Blade Number on the Generator Output Voltage at 75% Valve Opening.



The results obtained from the experimental study on the Micro Hydro Power Plant (PLTMH) prototype, which uses turbines with 3, 4, 5, and 6 blades, provide significant insights into the impact of the blade configuration and valve opening on turbine performance. Several key observations were made regarding the relationships among the number of blades, valve opening, turbine rotational speed (RPM), output voltage (Vdc), and water velocity.

#### 4. Discussion

The experimental data clearly demonstrate that valve opening has a profound effect on turbine performance. As the number of valve openings increases from 75% to 100%, all turbine configurations exhibit corresponding increases in water velocity, RPM, and output voltage. This can be attributed to the higher water flow rate at 100% valve opening, which generates more kinetic energy. The increased kinetic energy is then converted into rotational motion, resulting in a higher RPM and voltage output (Zainuddin et al., 2009 and Abdulkhaliq et al., 2023). Specifically, the water velocity increases with increasing valve opening due to the larger volume of water flowing through the turbine. At a 100% valve opening, the flow rate is maximized, which directly enhances the kinetic energy available to the turbine, allowing for better performance in terms of both rotational speed and electrical output. The increase in the output voltage at the 100% valve opening indicates improved energy conversion efficiency, as the turbine is able to extract more energy from the flowing water. Furthermore, although the wet height slightly increased, it remained relatively constant across the different blade configurations, suggesting that the physical water flow conditions were not drastically affected by the number of blades, as in previous studies (Thakur et al., 2024, Jaworska-Jóźwiak and Szymczyk, 2025).

One of the most important findings of this study is the influence of the number of turbine blades on performance. Experimental results have shown that increasing the number of blades leads to enhanced turbine efficiency (Wilcock et al., 2005 and Chen et al., 2025). As shown in Table 1, turbines with 5 or 6 blades consistently outperformed those with 3 or 4 blades in terms of both the RPM and output voltage. For example, the 6-blade turbine achieved the highest voltage (29 Vdc) and RPM (778.8) at 100% valve opening, whereas the 3-blade turbine reached only 25.46 Vdc and 433 RPM under the same conditions. The additional blades improve the turbine's ability to capture kinetic energy from the water flow (Hwang et al., 2009). The more blades there are, the more effectively the turbine can convert the energy from the moving water into rotational motion. This can be attributed to the fact that more blades increase the surface area that interacts with the flowing water, thereby enhancing the turbine's overall efficiency in extracting energy. The 3-blade configuration, while producing the lowest performance in terms of voltage and RPM, may be more suitable for low-power applications or environments with limited water flow. It is likely that this configuration could be more efficient in situations where power requirements are modest and where the water flow is not sufficient to justify the additional complexity and cost of a multiblade turbine (Wilberforce et al., 2023).

The relatively stable wet height across all the blade configurations suggests that variations in the number of blades did not significantly affect the physical characteristics of the water flow, at least within the scope of the parameters tested. The wet height is typically associated with the water level above the turbine, and its constancy across blade configurations implies that changes in the number of blades primarily influence turbine efficiency rather than altering the hydrodynamic conditions in the vicinity of the turbine. The turbine design can focus more on optimizing the rotational speed and voltage rather than adjusting for changes in the wet height (Njiri and Söffker, 2016; Hunt et al., 2024). The stable wet height across configurations supports the conclusion that the physical conditions of the water flow, such as depth and flow rate, are not significantly impacted by the number of blades, allowing engineers to focus on other parameters to optimize turbine design (Hunt et al., 2003 and Veers et al., 2008).

The data indicate that the 6-blade configuration is the most efficient for high-power applications, particularly when the valve is fully open (100%). This configuration maximizes the turbine's RPM and voltage, demonstrating its potential for applications that require high energy output. However, for situations with limited water flow or lower power needs, turbines with fewer blades (3 or 4) may be more appropriate. The configurations would likely perform efficiently under conditions with reduced flow, such as during dry seasons or in regions with lower water availability (Zebra et al., 2021). The three- or four-blade configurations, while delivering lower power outputs, are simpler and more cost effective. Their efficiency under lower flow conditions suggests that they could be more suitable for rural or off-grid applications where minimal energy generation is sufficient and where the cost of operation must be kept low (Hossain et al., 2024).

Turbines with more blades, particularly the 6-blade configuration, provide higher rotational speeds and voltage outputs, making them ideal for high-power applications. In contrast, turbines with fewer blades (3 or 4) perform well in situations where the water flow is limited or where lower power outputs are needed. Valve opening also plays a critical role, with larger openings allowing for more efficient energy conversion (Hossain et al., 2024 and Caban et al., 2013). The findings suggest that turbine design can be tailored to meet specific operational needs, and further research into varying flow rates and power calculations would enhance the optimization of PLTMH systems (Maulana et al., 2024).

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## 5. Conclusions

This study highlights the importance of turbine design and configuration in optimizing the efficiency of hydro water vortex turbines for sustainable hydroelectric power generation, and several conclusions can be drawn.

1. Increasing the number of turbine blades enhances the conversion of the kinetic energy of water into electrical energy, with the six-blade configuration achieving the highest performance. At a 100% valve opening, this configuration generated a maximum voltage of 29 Vdc at a water velocity of 1.46 m/s. Similarly, at a 75% valve opening, the six-blade turbine produced the highest voltage of 21.06 Vdc. These findings underscore the potential of blade optimization to improve energy output while minimizing environmental impact.

2. The results demonstrate that the water velocity and number of blades are critical factors in optimizing the performance of water vortex turbines. For high-flow conditions, turbines with more blades are recommended to maximize energy efficiency, whereas those with fewer blades are suitable for low-flow scenarios. This adaptability makes water vortex turbines promising and environmentally friendly renewable energy solutions. Further research is recommended to explore field implementation and refine designs for diverse water flow conditions, ensuring broader applicability and sustainability in real-world environments.

## Ethical considerations

Not applicable.

## Conflict of interest

The authors declare that they have no conflicts of interest.

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