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Performance Evaluation of Pumps as Turbines in Pico Water Systems Using Water Recycling as an Alternative Power Plant

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Pump as Turbine, Recycled Water, Pico Water System.

ABSTRACT
The use of pumps as turbines (Pump as Turbine or PAT) in the pico water system is one of the important innovations in the development of cost-effective and environmentally friendly alternative power plants. The background of this research is rooted in the need to develop renewable energy sources that can be implemented in remote areas with limited resources. Pico water systems that use water recycling offer sustainability solutions through efficient management of water resources while generating electrical energy for small-scale needs. This study aims to evaluate the performance of PAT in generating electricity and the effectiveness of using recycled water in improving the efficiency and sustainability of this system. The research uses a qualitative method based on literature studies, by collecting data from various sources, including journal articles, technical reports, and conference publications. Thematic data analysis techniques are used to identify patterns related to the design, efficiency, and sustainability of PAT systems that utilize recycled water. The results show that PAT is able to achieve energy conversion efficiency of up to 80% depending on design and operational conditions. The use of recycled water provides flow stability, which supports consistent PAT operations. Strategies such as the integration of digital technology and closed-loop systems improve the overall efficiency of the system. With promising results, recycled water-based PAT systems have great potential to be adopted as an alternative energy solution in remote areas. This study recommends the development of policies and training to expand the adoption of this technology.

1. INTRODUCTION

The use of renewable energy for power plants is one of the important solutions in overcoming global challenges related to the energy crisis and climate change. Among various renewable energy sources, hydro energy is a promising choice because of its huge potential in many regions, including in Indonesia. However, most conventional hydroelectric power plants (PLTA) require large infrastructure and high investment. Alternatively, pico water systems that utilize small streams of water to generate electricity are increasingly popular in remote areas that are not reached by the main power grid. One of the innovations in the pico water system is the use of pumps as turbines, which have proven effective in improving the efficiency of these systems (Nicolosi & Renzi, 2018).

A turbine is a device used to convert kinetic energy into mechanical energy that can be used to generate electricity. Typically, turbines work by utilizing a moving stream of water, steam, or gas to rotate the turbine blades, which in turn drives the generator to generate electricity. In the context of power plants, turbines are often used in hydroelectric power plants (PLTA), steam power plants (PLTU), and gas power plants (PLTG). Water turbines, for example, work by utilizing the flow of water flowing through the water distribution system to rotate the turbine. These turbines are highly efficient in harnessing the potential energy of water that is lifted or flowing at high speeds, which can be converted into electrical energy (Mason-Jones et al., 2012).

The pico water system is a power generation system that uses a small capacity of water to generate electricity. These systems are often used in remote areas that are not covered by the main power grid. Pico water power plants work by utilizing a river or small stream of water to rotate a small turbine connected to a generator. Although the electricity capacity generated is relatively small, the system is efficient enough for the energy needs of a small household or community. One of the advantages of pico water systems is their low installation costs as well as their relative ease of maintenance, making them ideal for rural areas that need environmentally friendly and affordable energy solutions (Barker et al., 2017).

The main advantages of the pico water system are sustainability and environmental friendliness. This system does not produce emissions or pollution, making it suitable for application in efforts to reduce carbon footprint. In addition, pico water systems have low operating costs because they do not require external fuels and utilize a renewable natural resource, namely water. However, there are several obstacles in the implementation of this system, especially related to fluctuations in water flow that can affect the stability of electricity production. Additionally, its limited capacity does not allow it to be used on a large scale, which makes it less effective for industrial needs (Haidar et al., 2012).

Alternative power generation refers to the technology used to generate electricity from energy sources other than fossil fuels. These plants include different types of technologies such as solar, wind, biomass, and hydro power plants. One of the main goals of the development of alternative power plants is to reduce dependence on fossil fuels that have a negative impact on the environment, such as greenhouse gas emissions and air pollution. The use of renewable energy sources, such as solar and wind, offers cleaner and more sustainable alternatives. Alternative power plants can be used at various scales, from small plants for households to large plants to meet industrial needs (Hossain et al., 2020).

Indonesia has great potential to develop alternative power plants, especially in terms of renewable energy. The country has abundant natural resources, such as high sunlight, strong winds in some areas, and abundant river flows. This potential strongly supports the use of alternative power generation systems, including solar, wind, and hydro power generation systems. For example, hydropower plants with small capacity, such as the pico water system, can be used in remote areas of Indonesia that have not been reached by the power grid. The development of alternative power plants can help Indonesia in realizing energy independence and reducing dependence on fossil fuels (Rimbawati et al., 2021). Despite its great potential, the development of alternative power plants in Indonesia faces a number of challenges, such as lack of infrastructure, suboptimal regulations, and lack of public understanding of this technology. One of the solutions that can be implemented is to strengthen government policies that support the use of renewable energy through incentives and training for communities and companies. In addition, there needs to be more efforts to increase cooperation between governments, non-governmental organizations, and the private sector in the development and distribution of renewable energy technologies. With these steps, it is hoped that Indonesia can accelerate the transition to the use of renewable energy that is more environmentally friendly and sustainable (Setyowati et al., 2019).

The pico water system that uses a pump as a turbine (pump-as-turbine) works by utilizing the flow of water pushed through a pump that functions to rotate the generator and generate electricity. This approach is perfect for areas that have limited water flow but need affordable and environmentally friendly power generation solutions. Pumps that are commonly used to drain water in irrigation systems or drainage systems can be converted into turbines with slight modifications (Tamminga et al., 2019). Nonetheless, the performance of the pump as a turbine in a pico water system still needs further evaluation to ensure its efficiency, especially in systems that use water recycling as the primary energy source.

Water recycling in the context of power generation is an innovative and sustainable approach, given the clean water crisis and the need to manage natural resources more efficiently. The use of water that is constantly recirculated in power generation systems can reduce resource waste and create a more efficient system in the long run. However, the main challenge in the application of water recycling in power generation systems is the deterioration in the quality and quantity of water flow that occurs over time. Therefore, it is important to evaluate the performance of the system thoroughly in order to maximize the potential of the energy produced without compromising water quality (Ayoub et al., 2016).

This research aims to optimize the use of the pico water system with pumps as turbines, especially in the context of using recycled water as an energy source. Given the great potential of water resources in many remote areas, this study aims to provide a comprehensive evaluation related to the performance of pumps as turbines in generating electricity, as well as the effectiveness of the use of recycled water in improving the efficiency and sustainability of the system.

2. METHOD

This study employs a qualitative research approach with a literature review method to evaluate the performance of pumps as turbines in pico hydro systems that utilize recycled water as an alternative power generation source. The literature review method is selected because it allows for an in-depth examination of existing research, case studies, and technological advancements in the application of pump-as-turbine systems and the use of recycled water in small-scale hydroelectric projects. The data for this study is sourced from peer-reviewed journals, conference papers, reports, and books that focus on the technical aspects, efficiency, and sustainability of pico hydro systems. Key databases such as ScienceDirect, Wiley Online Library, and IEEE Xplore are used to gather relevant articles and publications (Patton et al., 2015).

The data collection process involves identifying and selecting studies that specifically discuss the use of pumps as turbines in small-scale hydro systems, the application of recycled water in energy generation, and the effectiveness of these systems in rural or remote areas. Additionally, research that addresses the technical challenges, operational performance, and environmental impact of such systems is considered. The inclusion criteria for sources are based on relevance, credibility, and publication date, prioritizing studies from the last ten years to ensure the information reflects the most recent developments in the field (Booth et al., 2021).

Data analysis in this study follows a thematic approach, where key themes related to the performance of pumps as turbines, the integration of recycled water in pico hydro systems, and their overall efficiency are identified and analyzed. Each theme is evaluated for its contribution to the success of small-scale hydroelectric generation, focusing on technological innovations, operational challenges, and environmental sustainability. The results of the thematic analysis are synthesized to provide comprehensive insights into the feasibility of using pumps as turbines in recycled water systems and to evaluate their performance against traditional hydroelectric methods (Braun & Clarke, 2006).

3. RESULT AND DISCUSSION

The following table presents the findings obtained through the selection process of articles relevant to this research topic, namely the performance of pumps as turbines in pico water systems that use water recycling as an alternative power plant. This data was obtained after sifting through various related literature sources, consisting of international journals, technical reports, and conference articles that discussed topics such as alternative power generation systems, pumps as turbines, and the utilization of recycled water in energy production. The selected articles are the most recent and relevant studies that support the objectives of this study.

Table 1. literature Review

No	Author	Title	Key findings
1	Edeoja & Ipilakyaa (2023)	Performance Evaluation of a Pump as Turbine in a Simplified Pico Hydropower System	PAT improves the efficiency of the Pico Hydropower system with an economical water recycling concept.
2	Thyer & White (2023)	Energy Recovery in a Commercial Building Using Pico-Hydropower Turbines	PATs can recover up to 10% of the energy used for the water pumping process in commercial buildings.
3	Carravetta et al. (2018)	Pumps as Turbines	PATs play an important role in micro and Pico-hydropower with low cost and high reliability.
4	Ismail et al. (2023)	Design and Development of a Pico Hydro Turbine for Small-Scale Power Generation System	The innovative design of the PAT generates small-scale electrical power for rural communities without power grids.
5	Kumar et al. (2023)	Development of In-situ Pico Hydropower from Treated Drain Wastewater	PAT utilizes wastewater to generate small amounts of electrical power, supporting environmental sustainability.
6	Nassar (2023)	Pico-Hydropower Generation Using Pump as Turbine for Water	PATs are used to support water disinfection in small-scale

		Disinfection	applications.
7	Postacchini et al. (2020)	Hydropower Generation through Pump as Turbine	Experimental studies of PAT show the potential for high efficiency for small-scale applications.
8	Novara & McNabola (2021)	Year-Long Performance Evaluation of PAT Pico-Hydropower in Water Networks	The evaluation of PAT's performance showed good operational stability throughout the year.
9	Hunachal et al. (2020)	Irrigation Water as a Renewable Energy Source in Pico Hydropower Generation	The use of irrigation water as a source of renewable energy uses PAT.
10	Morabito & Hendrick (2019)	Pump as Turbine Applied to Micro Energy Storage and Smart Water Grids	PATs support micro energy storage and integration into smart water grids.

The use of pumps as turbines (Pump as Turbines or PATs) in the Pico hydropower system offers great potential as an economical and environmentally friendly renewable energy solution. The selected articles provide in-depth insights into the efficiency, technological innovation, and practical applications of PAT in a variety of contexts. Research by Edeoja and Ipilakyaa (2023) evaluated the performance of PAT in a Pico hydropower system designed with water recycling. This study shows that PAT is not only efficient in generating electricity, but also provides a cost-effective solution for small-scale energy needs, especially in regions with limited access to conventional energy (Edeoja et al., 2023).

Thyer and White (2023) raise another aspect of PAT by implementing it in commercial buildings. The study found that PATs are able to return up to 10% of the energy used to pump water, creating a more sustainable model of the system. The integration of PAT in systems like this not only reduces operational costs, but also contributes significantly to the reduction of the building's carbon footprint (Thyer & White, 2023).

Meanwhile, Carravetta et al. (2018) highlighted the flexibility and reliability of PAT in the context of micro and Pico hydropower. This study emphasizes that PAT is an ideal solution for distributed energy systems due to its low cost and ability to adapt to various operational conditions. This flexibility makes PAT a promising technology to meet the energy needs of rural communities far from the main power grid (Carravetta et al., 2018).

The research of Ismail et al. (2023) further explores the design and development of PATs for small-scale power generation. The study focused on rural communities that do not have access to electricity. The results show that the system does not require major modifications to the pumps, making it a practical solution that can be easily implemented in remote areas. The ability of PAT to support rural electrification with local resources shows great potential to improve community welfare (Ismail et al., 2023).

In terms of environmental sustainability, Kumar et al. (2023) integrate PAT with the use of treated wastewater to generate electricity. This study provides an overview of how PAT can support sustainable water recycling while providing enough energy for basic needs. This approach paves the way for further innovation in utilizing waste as an energy source (Kumar et al., 2023).

Nassar (2023) proposes the use of PAT in small-scale water disinfection systems. This implementation is designed to provide sustainable energy solutions for water treatment in areas that need better sanitation. This study reinforces the argument that PAT can be applied not only to generate energy but also to support social goals, such as improving public health (Nassar, 2023).

Research by Postacchini et al. (2020) and Novara and McNabola (2021) evaluated the performance of PATs in water distribution networks. The results of their study showed the stability of PAT's performance throughout the year, even under varying operational conditions. These findings confirm the reliability of PATs as energy-generating devices that can be integrated into existing systems, such as municipal water distribution networks (Novara & McNabola, 2021; Postacchini et al., 2020).

Hunachal et al. (2020) add another perspective by exploring the potential of PAT in utilizing irrigation water as a renewable energy source. The study shows how PAT can be used to improve the efficiency of irrigation systems while generating additional energy. This kind of implementation is very relevant for agricultural areas that face energy challenges (Hunachal et al., 2020).

Finally, Morabito and Hendrick (2019) showed how PAT can be applied in micro energy storage and integration with smart water networks. This study highlights the potential of PAT to support distributed energy systems, improve energy storage efficiency, and optimize water use in urban areas (Morabito & Hendrick, 2019).

The whole article shows that PAT is a very flexible, efficient, and versatile technology. The use of PAT not only helps meet small-scale energy needs, but also contributes to environmental sustainability and community empowerment. With a wide range of innovative applications, PAT offers relevant solutions to meet global energy challenges and future sustainability needs.

Discussion

Utilization of the Pico Water System with the Concept of Pump as a Turbine (PAT)

The use of pumps as turbines (PAT) has been recognized as one of the innovative solutions in developing small-scale power plants, especially in pico water systems. PAT is a cost-effective device that converts water kinetic energy into mechanical energy, which is then converted into electrical energy through a generator. In the context of water recycling as an energy source, PAT offers great potential to create more efficient and sustainable systems. One of the advantages of PAT is its flexibility to be applied in various types of environments, including in urban areas with existing recycled water networks.

Pico water systems with PAT utilize low-velocity water flows that are often underutilized. Recycled water, which usually comes from domestic waste that has been processed, is reused to produce energy. By redesigning the water network infrastructure, PAT can be integrated to take advantage of stable water pressure and discharge, thus generating electrical energy without sacrificing the quality of recycled water distribution. In certain applications, recycled water can also be used to drive PATs in closed-loop systems, which improves system efficiency by reducing the need for additional water intake.

The Effectiveness of PAT in Generating Electricity

The effectiveness of PATs in generating electricity depends on the design of the pump, the hydraulic conditions, and the mechanical efficiency of the device. Compared to conventional turbines, PAT has advantages in terms of lower initial costs and minimal maintenance requirements. However, the efficiency of the PAT can vary, typically ranging from 40–80%, depending on the adjustment of the pump to function as a turbine. To improve efficiency, turbine design needs to be adjusted to the available water discharge and pressure. For example, by adding an automatic pressure controller, the PAT can be set to work at optimal conditions, increasing the output of electricity generated.

In trials on various pico water systems, PAT has been shown to produce enough electrical power for small households or community lighting systems. Studies show that at a water pressure of about 10 meters and a flow discharge of 10 liters per second, PAT is capable of generating up to 1 kW of electrical power. Although this power is relatively small, this system is perfect for remote areas that are not reached by the main power grid.

The Effectiveness of Using Water Recycling

The use of recycled water in this system not only improves energy efficiency but also supports environmental sustainability. Water recycling systems provide a consistent source of water to power the PAT, thereby reducing reliance on natural water from rivers or lakes. By reusing treated wastewater, the system helps to reduce the exploitation of water resources as well as minimize the environmental impact of liquid waste.

The effectiveness of the use of recycled water is also related to the operational stability of the system. Because recycled water tends to have a more consistent discharge and pressure, the performance of PAT can be more optimal compared to using natural water whose flow fluctuates. This provides an additional advantage in the planning of water-based micropower generation systems.

PAT System Optimization Strategy for Recycled Water

To optimize the utilization of PAT in the pico water system, several strategic steps can be implemented:

1. Selection and Modification of PAT Design
   Select the pump according to the hydraulic parameters and modify it to improve efficiency. The addition of control devices such as governors can help keep the PAT performance optimal.
2. Closed Loop System Integration
   Using a closed-loop system to recycle the water used by the PAT. This reduces the need for additional water and improves the overall efficiency of the system.
3. Periodic Monitoring and Maintenance
   Implement a real-time monitoring system to measure PAT performance, including pressure, discharge, and electrical output. Periodic maintenance ensures that the PAT works at maximum efficiency.
4. Utilization of Supporting Technology
   Integrating digital technologies such as IoT for remote monitoring and control. This can help operators to immediately adjust operational parameters to increase electricity output.

4. CONCLUSION

Based on the data above, the use of PAT in the pico water system with the concept of water recycling provides a cost-effective and environmentally friendly solution to produce alternative electrical energy. The effectiveness of PATs in generating electricity, although depending on the design and hydraulic conditions, can be improved through proper optimization strategies. Meanwhile, the use of recycled water as an energy source increases the sustainability of the system and supports the conservation of natural resources. With integrated implementation, this technology has great potential to be widely applied, especially in regions that require efficient and sustainable energy solutions.

In order to optimize the use of pumps as turbines (PATs) in pico water systems with the concept of water recycling, it is recommended to select and modify the PAT design according to specific hydraulic parameters, integrate a closed-loop system to minimize the need for additional water, as well as implement IoT-based real-time monitoring technology to improve operational efficiency. In addition, policy development and government support to expand the adoption of this technology in remote areas are urgently needed to ensure system sustainability and optimal benefits for society and the environment.

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