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https://doi.org/10.5109/7395752

出版情報：Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 11, pp.1826-1831, 2025-10-30. International Exchange and Innovation Conference on Engineering & Sciences
バージョン：
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Hydrokinetic Turbine for Home Power

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Abstract: *The Hydrokinetic Turbine is a new technology that can extract energy from low water flow rates and does not utilize a dam & hydraulic head like traditional turbines. This research project was to develop an Axial Water Turbine to satisfy the electricity needs in rural areas, which do not have adequate grid access. Sungai Pahang was identified as a suitable area for the deployment of the turbine because of its low water flow rate. The turbine was designed using Siemens NX 10 with Nastran for 3D modelling and analysis and was then built with the turbine blades and supporting structure. The system produced voltage readings between 4.61V and 5.47V with a rotational speed of 1528 RPM. The turbine also demonstrated its capability of producing useful work by powering three light bulbs and a standing fan with 82.72 W of total power. Overall, this product is practical for rural communities, providing sustainable energy that can be accessed without dependence on the electricity grid.*

Keywords: Hydrokinetic Turbine; Renewable Energy; Rural Electrification; Micro-Hydropower System

1. INTRODUCTION

These Across the globe, 1.4-1.6 billion people have no access to electricity at all, while another one billion are dependent on unreliable electrical grids. Many of those lacking access to modern energy live in rural areas; thus, decentralised, off-grid energy projects will play a vital role in achieving [1]. Hydrokinetic turbines are a potentially appealing decentralized energy opportunity for rural areas that may be away from the grid or may have poor or unreliable grid service. Hydrokinetic turbines are capable of converting the kinetic energy from flowing water into electrical energy, unlike other forms of hydropower which need a hydraulic head developed to harness the energy [2]. Hydrokinetic turbines provide a valuable opportunity for localized energy generation in areas that do not have a reliable source of electricity now, often from the grid [3]. Hydrokinetic energy technology is a greatly underutilized resource that can be useful for rural economic development and improving the quality of life where electricity is not available [4]. There is a considerable opportunity for these technologies to provide a solution to remote communities in rural areas of Canada, and help unlock resources and provide services to spur economic development, sustainable development, and improve quality of life in rural areas with poor or unreliable or no access to electricity. Deployments of renewable energy technologies can be a very substantial game changer solution to rural areas with certain environmental and locational factors [5]. Hydrokinetic and related energy solutions can developed for rural applications with dispersed populations and challenging geography, while also providing a tool to move regional and national partitioning to energy independence and sustainable development. Several factors ultimately determine the viability of hydrokinetic turbine systems. For example: (1) the ability to rely on a consistent flow of water; (2) the efficiency the turbine can convert kinetic energy to electricity; and (3) the general cost effectiveness of the turbine system in its entirety [4]. The amount of power available from a hydrokinetic turbine is proportional to the cubes of the velocity of water and swept area of the rotor; thus, it is crucial to identify sites demonstrating high flow rates and design the turbine properly [5, 6]. Integrating another form of renewable energy with an energy storage mechanism is an innovative way to address issues with renewable energy sources in general. Small hydro power is a cost-effective and environmentally friendly technology for electricity generation [7]. A thorough resource assessment and feasibility study should be conducted to assess the extent that hydrokinetic technology can be used at a specific location. The environmental benefits of hydrokinetic turbines stand out compared to conventional hydropower. Small hydro turbines in existing canals of irrigation networks not only produce energy, but enhance water efficiency overall [8]. Since rural area development inevitably leads to broader eco-related approaches, the lower environmental impact of hydrokinetic systems makes them an appealing alternative. The modular aspect of hydrokinetic turbines allows for flexible implementation and scalability, which can allow communities to generate more power when demand expands [4]. Finally, hybrid renewable energy systems that incorporate hydrokinetic turbines can improve the reliability and resiliency of rural energy grids that face intermittency issues related to any single renewable source. The turbines produce electricity from the free-flowing water in a river or stream and do not rely upon a waterhead to produce electricity. Many types of turbines can be found [9]. However, this project is to gain improvement of this mechanism to apply in rural areas by improving the Hydrokinetic Turbine, which is placed in a river stream. The main objective of this project is to generate electricity and supply this green energy in rural areas for a better living for the remote community in Sungai Pahang. The hydrokinetic turbine could be submerged in the river or could be placed on the surface of the water using a pontoon [10]. The characteristic that suit to Pahang river is propeller turbine which reaction type and used depth of river below 5 meter.

2. LITERATURE REVIEW

Hydrokinetic turbines are an appealing option for rural areas for generating electricity, especially for areas with rivers, streams or tidal flow. Hydrokinetic turbines convert the kinetic energy of moving water into mechanical energy which is then converted into electrical energy [4]. Hydrokinetic turbines differ from hydroelectric dams in that hydrokinetic turbines do not need to be connected to large impoundments or make diversions meaning they tend to have less of an impact on the environment and can serve as smaller scale, decentralized, electricity generation source [11]. The successful use of hydrokinetic energy will be dependent upon an understanding of the resource potential, technology of the turbine, and the plans for integrating the device. The modernization of rural electricity systems is vital to economic development and quality of life improvement for rural populations without access to electricity and electrification project [12]. Hydrokinetic turbines have the potential to provide future energy independence and lessen future reliance on fossil-based resources when combined with other renewable sources like solar photovoltaic and wind turbines [13]. It can be overwhelming to think about one of the possible hydrokinetic systems in a rural environment because there are many aspects that need to be considered that will impact subsequent design decisions; the hydrology of the area and what energy loads are expected and whether the community will be on-board [5]. Access to reliable electricity is a catalyst for socio-economic development in the multiple rural community contexts. Enhancing access to reliable electricity in rural contexts will lead to additional access to educational opportunities, healthcare services, and economic opportunities [5]. Some renewable resources, for example, wind, solar energy, and hydro-power sources have an exceptional possible role to play in allowing rural areas save energy, primarily due to it being the possible unlimited recoverable resources, and the reliability and cleanliness of access [14]. Hydrokinetic turbines provide long-term electricity access to rural areas, especially when communities are located near a waterway, as they generate electricity from kinetic energy, harnessed by flowing water [5]. Hydrokinetic turbines alleviate the need for significant damming and associated reservoirs. In addition, electrification of rural areas can help prevent youth outflows from their communities by keeping them engaged in productive livelihood activities such as agriculture and animal husbandry, and by improving communication and connectivity among rural and urban centres and reducing phenomenon of rural youth migration towards urban centres [4]. Hydrokinetic turbine technology supports decentralized methods for power generation, minimizing transmission losses and bolstering energy security in isolated regions. Here hybrid renewable energy systems, in which two or more renewable energy sources, such as micro-hydro with solar or wind, are employed, are particularly useful in rural areas where energy demand can fluctuate and one source alone likely will not provide consistent power [5]. They capitalize on the advantages presented by each resource and any synergism from the integration of resources, to guarantee uninterrupted power supply, which is critical for remote communities [15]. Using hydrokinetic turbines with other renewable energy, like solar photovoltaic systems, has the potential to fuel robust and reliable hybrid power systems for rural small-scale applications. High initial costs of renewable energy hybrid systems have hindered broader implementation of hybrid systems in developing countries and highlight the importance of designing lower cost and optimized hybrid systems. Micro-grids, which usually rely on renewable energy sources like hydrokinetic or solar that are readily available in these communities, may facilitate low cost ideas to eliminate energy poverty, are easy to deploy, install, and operate, and can be designed to meet a community's specific needs [16]. The costs of renewable energy technologies and energy storage continue to decline making micro-grids attractive options for rural electrification [17].

3. METHODOLOGY

3.1 Project Flowchart

In this project, the focus is on the hydrokinetic turbine, which allows the water to flow through the blade twice. The first pass is when the water flows from the outside of the blade to the inlet. The second pass is from the inlet to the outlet of the turbine. Crossflow micro turbines can operate with a head between 5m to 200 m. The system allows the water to pass through the runner and crosses it two times before leaving the turbines. The simple design makes the crossflow turbine easy to maintain and has a lower cost compared to other turbines. The capacity for micro turbines is smaller compared to other hydro power plants' turbines. With this smaller scale of turbine, it is the best solution for a small range of power applications. This system does not require dams to generate electricity and, more importantly, has a low investment cost and a reliable maintenance cost. This system depends on the necessary flow rate of run river flow rate to convert from kinetic energy to electric energy. Thus, this system is environmentally safe for small-scale power applications that are not more than 1000kW. In designing a hydrokinetic turbine, some criteria need to be taken care of. Firstly, material, hydrokinetic turbine commonly made of an alloy, since these materials are anti-corrosion and are easily cast and machined into shape. Stainless steel is the most used material in blade turbines because of long long-lasting properties. Then, diameter selection is associated with the velocity of water impacting the blade, which is directly related to available head. The higher the head, the smaller the blade diameter for a given constant shaft speed. For practicality, blade for smaller turbines is usually limited to just a few. The blade's speed is adjusted using the generator field about battery voltage or using belt pulley ratios about the output frequency of direct AC systems. However, in producing small-scale electricity, axial water turbine blades a need is only 3, with dimensions 0.5-2.75 meters, which is suit for 0.5-2.0 m/s velocity of water. The torque of the turbine based on pressure per angular velocity is 14.327 N. Since the scale of hydro kinetic turbine is relatively small, it will not impede habitat connectivity that causes restriction of migrating patterns and decreases the ability of functional groups to perform their roles in the seascape, like the large turbine installations.

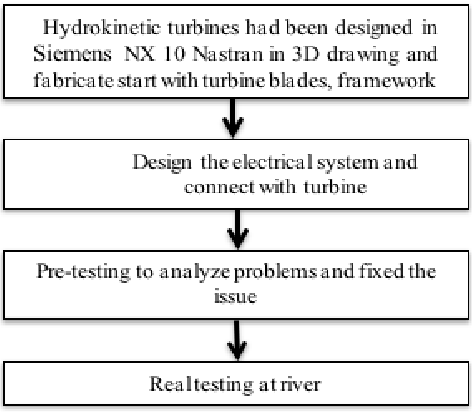

Fig. 1. Project Flowchart.

3.2 Mechanical Part

Mechanical part starts with the designing stage by using Siemens NX 10 Nastran software as in Fig. 2. The Fig. 3 is the Hydrokinetic Turbine 3D modelling design. The dimension of the design is 1500mm x 550mm x 650mm, the material structure is done by using carbon steel, mild steel and stainless steel and type of machine used to produce the design are shearing machine, rolling machine, hand grinder, miter saw, Metal Inert Gases (MIG) welding, hand drill and air rivet.

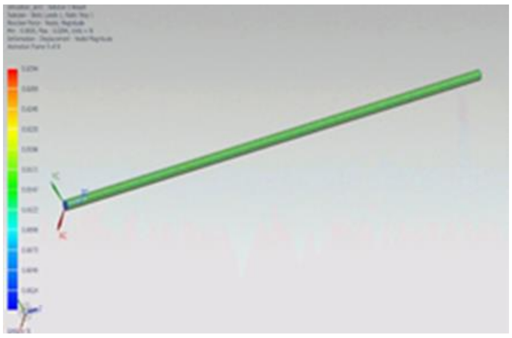

Fig. 2. Von Mises Stress (Nodal Value) analysis.

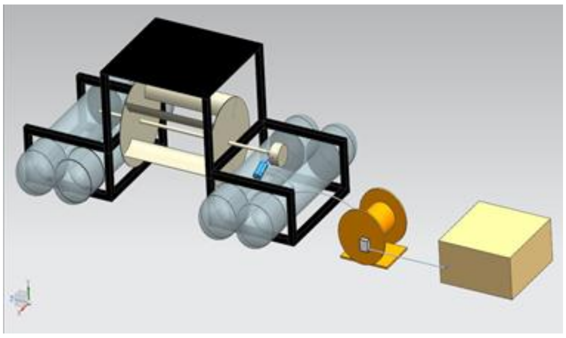

Fig. 3. 3D modelling design

The below figures; Fig. 4 to Fig. 11, shows the fabrication works that been conducted to fabricate the hydrokinetic turbine where the fabrication process such as rolling process, drilling process, riveting process and drilling process been carried out in the fabrication works.

Fig. 4. Cutting a metal sheet using a shearing machine.

Fig. 5. Rolling process in making blades using a roller machine.

Fig. 6. Drilling process on blades using a hand drill.

Fig. 7. Riveting process on blades used an air rivet.

Fig. 8. Grinding excess burr on framework used hand grinder.

Fig. 9. Cutting framework workpiece using a mitre saw.

Fig. 10. Attach framework used for Metal Inert Gases (MIG) welding.

Fig. 11. Finishing process by painting the framework to avoid corrosion.

3.3 Electrical Part

A sealed lead-acid storage battery, as in Fig. 12, having a long trickle life, is excellent in the welded strength between the container cover and the top lid covering the part of the container cover. A vent valve is provided, which has a high reliability. The battery comprises: a container for accommodating an electrode group, a container cover for closing an open end of the container by being bonded to the open end of the container with a resin adhesive, and a top lid for covering a part of the container cover where a vent valve is provided by being bonded to the container cover using ultrasonic welding [18].

Fig. 12. Lead-acid battery.

The DC Permanent Magnet Motor Generator (PMG), as in Fig. 13, is mostly used for wind and water turbines. The PMG system is intentional to convert mechanical energy obtained from an external source into electrical energy as the output. The PMG is chosen because the cost of this generator is affordable, yet it offers quite satisfying results. Many permanent magnet motor drives use an open-loop form of torque control, based on the assumption that output torque is proportional to applied current. Many high-performance permanent magnet motors use surface-mounted magnets on a rotor with a large rotor-stator airgap [19].

Fig. 13. DC Permanent magnet motor generator

A power inverter, as in Fig. 14, is a machine that can transform 12V DC to 240V AC for home appliances. Electronic inverters can be used to produce this kind of smoothly varying AC output from a DC input. Inverters use electronic components called inductors and capacitors to make the output current rise and fall more gradually than the abrupt, on/off-switching square wave output you get with a basic inverter. Inverters can also be used with transformers to change a certain DC input voltage into a completely different AC output voltage (either higher or lower), but the output power must always be less than the input power; it follows from the conservation of energy that an inverter [20].

Fig. 14. Power inverter.

4. RESULTS AND DICUSSION

The graph in Fig. 15 shows six points of data showing how the rotational speed (RPM) of turbines varied. First, the RPM at the start was approximately 1490, but recorded a slight drop at the second data point, at approximately 1470 RPM. This drop appears inconsequential and could be attributed to a temporarily reduced driving force (wind speed or water flow, for instance), or could be reflective of initial system instability. From this point on, the RPM consistently increased, beginning at point 3, to point 6, ending at approximately 1530 RPM. This increase indicates that the driving conditions improved—either, the input driving force was strengthened at some point further into the data points, or the turbine system was able to either operate more efficiently or more stably, or even both, at each of the recorded data points. The upward trend in RPM confirms that this is a typical extension of a ramped-up behaviour, often see in mechanical systems as they undergo some changes or improvements. The graph in Fig. 16, shows the voltage output of the turbines for the same six data points. Similar to the graph of RPM, the initial section of the graph (or first three data points) demonstrates a relative stability in the voltage produced by the turbines. The turbine voltage fluctuated, but remained close to 4.6 to 4.7 volts. When looking at data points 3 and 4, the voltage takes a dramatic increase, increasing roughly to 5.4 volts. From here the voltage output increased more gradually, eventually reaching 5.5 volts by the sixth data point. This spike in voltage closely mirrors the increase in RPM demonstrated in the first graph. Given that the voltage output produced my turbines is closely linked to the turbines' RPM, this correlation is expected. The spike between data points 3 and 4 likely reflects a significant enhancement in input quality, or possible turbine performance, resulting in improved outputs. The comparison between output voltage and angular speed of the turbine is listed as in Table 1.

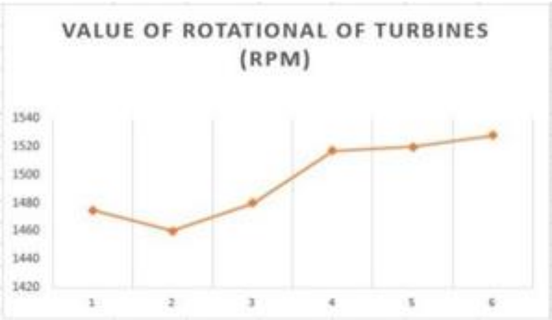

Fig. 15. The values of the rotational speed of turbines in unit RPM.

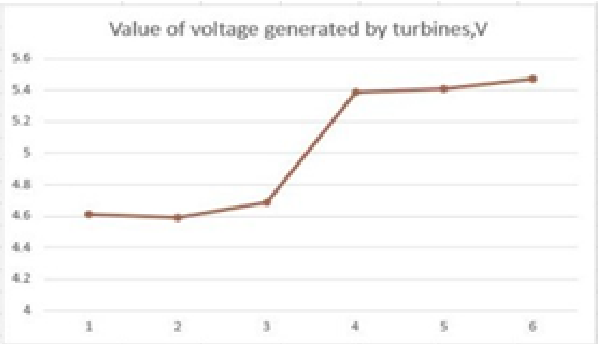

Fig. 16. The value of voltage generated by turbines in unit V.

Table 1. Table of values of voltage after step-up and angular speed

Hour	Output Voltage, V	ω, angular speed in (rad/s)
1	12.2	154.46
2	11.9	152.89
3	12.9	154.99
4	13.6	158.86
5	13.8	159.17
6	14.4	160.01

The Table 1 above shows the relationship between output voltage and angular speed for a duration of six hours. Each thermodynamic hour was one hour of measurement output voltage in volts, to the corresponding angular speed in radians per second (rad/s). The opposing data indicates a positive relationship between voltage and angular speed output. For example, as outlined below, in hour 1 the measured output voltage was 12.2 V with an angular speed of 154.46 rad/s. In hour 6, the measured output voltage was 14.4 V with a corresponding angular speed of 160.01 rad/s.

5. CONCLUSION

The turbine performed flawlessly during the testing period, reaching a maximum rotational speed of 1528 RPM and maximum linear speed of 316.9m/min. This presented all of the results indicated that the turbine system's mechanical components were operating with efficiency and effectively within the limits of the test conditions. The turbines' voltage is an understandable means from 4.61V to 5.47V which correspondingly supplies appropriately usable and usable output from mains for localized electrical needs. The electrical energy yielded was enough to successfully power viz three light bulbs and a standing fan - the fan consuming a total of 82.72 watts. This substantially stabilizes the turbine's ability to meet basic residential energy needs, and indicates viability for any applied effort towards small-scale or off-grid energy systems. In the future, one way to improve the turbine system is to increase the system's output voltage. A feasible solution is the introduction of gearing, which effectively increases the speed of the generator shaft in relation to the turbine's primary rotation. If the RPM of the generator can be increased by gearing, the voltage output should likewise increase, enabling it to power higher voltage electrical loads or to store surplus energy in batteries. By having this allowance, it will create a favourable benefit in terms of the overall efficiency and utility of the turbine system and the energy generation capacities.

6. ACKNOWEDGEMENT

We are sincerely grateful to ALLAH "S.W.T", the most merciful and most compassionate, for his blessings. Had it not been due to His will and favour, the completion of this study would not have been achievable. First of all, we would like to express our gratitude to our most dedicated project supervisor, Mr Muhamad Ridzuan Bin Radin Muhamad Amin and Teaching Engineer Mr Mohd Azlan Bin Sayuti for their time, moral support, suggestions, assistance, supervision and helped us a lot with valuable advices and constructive criticism throughout the study. Thanks to our parents, family and friends for being supportive and helpful.

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