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APPLICATION OF CROSS FLOW TURBINE WITH MULTI NOZZLE IN REMOTE AREAS

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ABSTRACT

The application of the muti nozzle cross flow turbine as a power plant in remote areas that is not affordable by electricity supply and transportation is very effective and suitable in rural areas that utilize the potential energy of water as a small and large scale energy source. The results of research on the use of multi-nozzle cross flow turbines are able to produce turbine power of 5.011 kWatt as a driving generator that produces 4.259 kWatt of electric power, strongly supporting the provision of electrical energy for remote areas.

Key words: Cross Flow Turbine, Multi Nozzle, Remote Areas

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1. INTRODUCTION

Electrical energy as one of the main factors in supporting the development of national development. In Indonesia, this development was marked by population growth and industrial activities which resulted in increased electricity consumption. Increased energy requirements for more efficient electricity generation can meet electricity needs in remote areas [1]. Meeting the needs of electrical energy in remote areas is very appropriate with the application of micro hydro power technology because the construction is simple and applicable [2]. The main parts of micro hydro power plants are penstoc pipes as water lines, water turbines and generators, control panels, and power transmission networks [3]. At present cross flow turbines get a lot of attention because they can be applied to a more diverse and economical flow range and head. The use of this turbine for the same power as other types of water turbines can save the cost of making an initial drive up to 50% of the use of water wheels with the same material, because the dimensions of the cross flow turbine are smaller. The materials needed to make cross flow turbines are much less and use local materials, making it cheaper [4].

Since the advent of cross flow water turbines, much progress has been made through research through laboratory experimental methods especially on turbine design parameters such as angle of arrival, number of blades, runner diameter ratio, runner width, and nozzle dimensions [5]. Some researchers also conduct laboratory studies on cross flow turbines that aim to show a series of results of cross flow turbine tests made based on different specifications to improve optimal turbine performance. Water turbine is a turbine that uses water as its working fluid and a very simple power generation consisting of water sources, water reservoirs, water turbines and generators. The turbine functions to change the potential energy as shown in Figure 1 and the kinetic water into mechanical power [6].

Figure 1 Remote Regional Energy Sources

Turbines consist of rows of rotating blades (rotors) and non-rotating components (stators). Utilization of water flow velocity as an impulse turbine drive in the presence of a reaction force of water flow entering and leaving the rotor blades. Turbine rotation occurs when the speed of water hits the rotor blades and the rotor moves swivel, the rotor blades cause reaction forces that produce mechanical energy [7].

This research was conducted to implement and test the performance of a multi-nozzle cross flow turbine with a turbine rotor that has the same number of blades as a multi-nozzle as a driving generator for electricity. The purpose of this research activity is to study the increase in the performance of micro hydro power plants, and determine the electric power capacity and efficiency produced by a prototype multi-nozzle cross flow turbine.

The definition of a water turbine derived from the word "turbine" is taken from the Latin translation of the word "whirling" (rotation) or vortex so that a water turbine is a turbine that uses water as its working fluid to produce power. This water turbine is usually used to produce electricity for industry. [8] It is now most commonly used to drive electric generators and is widely used as a renewable energy source.

A simple turbine has a moving part and fluid that drives the blade of the runner to spin and produces mechanical energy to drive the rotor. The development of turbines requires quite a long period of time, during the industrial revolution using scientific methods and principles. The basic difference between the initial water turbine and the waterwheel is the rotating water component which energizes the rotating shaft and allows the turbine to provide more power with smaller components with faster rotation that utilize higher water fall or higher heads. The parts of the water turbine are (1). The rotor is the rotating part of the system consisting of the blades which functions to receive the jet load that is sprayed by the nozzle. (2). Nozzle is for emitting and directing water into the turbine blade. (3). The shaft functions to continue mechanical power in the form of rotary motion produced by the blade. (4) The cushion functions as a support and shaft holder with the aim that it does not wear rotot and stator components in the system. (5). Stator is the stationary part of the system consisting of a nozzle holder which functions to continue the flow of fluid so that the pressure and flow velocity of the fluid used in the large system of the turbine house functions as the domicile of the existing components [9].

Based on changes in the momentum of the working fluid, water turbines can be divided into two types, namely:

1.1. Reaction turbine.

Reaction turbines are turbines that utilize potential energy to produce motion energy. Blades in the reaction turbine have a special profile that causes a decrease in water pressure during the blade [10]. The types of reaction turbines include:

1.1.1. Francis Turbine

Francis turbine is a reaction turbine that is installed between a source of high pressure water at the inlet and low pressure water at the exit with a directing blade, turbine inlet water tangentially as a permanent or non-permanent blade [11].

1.1.2. Kaplan Turbine

The Kaplan turbine works using the principle of reaction, has a road wheel that functions to produce thrust and serves to get the force that is the rotary force that can produce torque on the turbine shaft. Kaplan turbines are widely used in river hydroelectric power plant installations, because these turbines have the advantage of being able to adjust the head with a smaller turbine wheel size and can be coupled directly with a generator [12].

1.2. Impulse Turbine

Impulse turbines are turbines that utilize the potential energy of water converted into kinetic energy in the nozzle. The nozzle with a high speed water jet hits the turbine blade so that the flow velocity changes so that the momentum changes [13]. As a result of changes in the momentum of the turbine wheel will rotate. Impulse turbines have the same pressure because the flow of water that comes out of the nozzle is the same as the pressure of the surrounding atmosphere.

The types of impulse turbines include:

1.2.1. Pelton Turbine

Pelton turbines are the most efficient type of water turbine, and are suitable for water sources that have relatively high heads at low flow capacity levels. In Figure 2 the runner of the small Pelton turbine is used to tap water energy from rivers in the mountains. These small units are recommended for a minimum head of 30 meters to produce a significant increase in power. The Pelton turbine consists of a set of road blades that are rotated by jets of water that are sprayed from one or more nozzles. The shape of the turbine blade consists of two symmetrical parts, so that the jet of water will hit the middle of the blade and the jet will turn in both directions [14]. This causes the blade to reverse the jet water well and free the blade from the side forces so that the conversion of kinetic energy into mechanical energy.

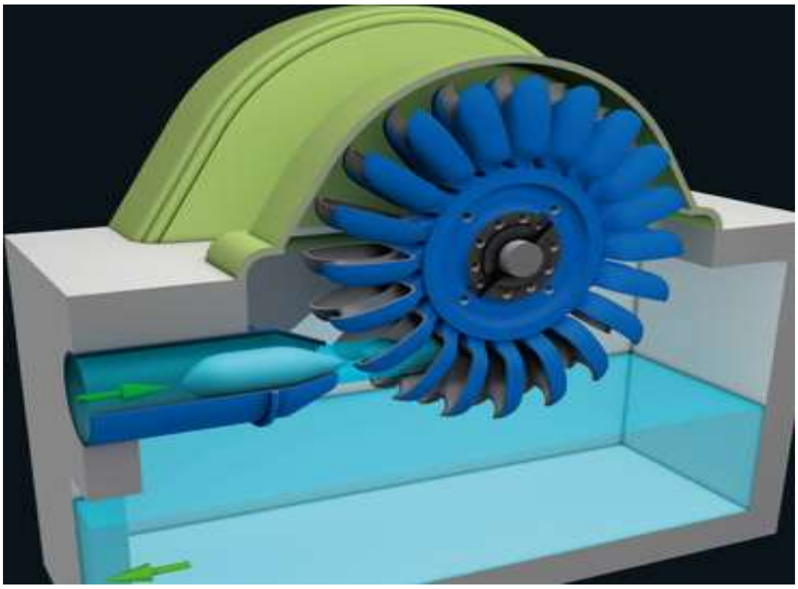

Figure 2 Pelton Turbine

(Source:https://images.search.yahoo.com)

1.2.2. Turgo turbine

Turgo turbines are impulse type water turbines that are designed for medium heads and can operate on heads from 30 to 300 meters. Turgo turbines have several advantages compared to Francis and Pelton types for certain applications, including making runners more easily compared to Pelton types, does not require turbine houses that are soundproof, have higher specific speeds and can handle greater water flow, efficiency around 80 to 90%. Figure 3 shows the shape of the Turgo turbine runner like a Pelton runner that is split in half [15]. For the same strength, the Turgo runner is half the diameter of the Pelton runner, and twice the speed. The Turgo turbine can handle a larger flow of water than Pelton because water output does not interfere with adjacent blades. The components of the Turgo turbine are shown in the following figure which have major components including the generator, inlet nozzle, and runner

Figure 3 Turgo Turbine

(Source: https://images.search.yahoo.com)

1.2.3. Cross flow turbine

Cross flow turbine is a turbine whose working fluid flow is carried out on the runner by cross flow in the simplest form consisting of a runner and nozzle. The runner is composed of two parallel plates connected by a series of curved blades. Cross flow turbine nozzle which serves to direct the flow to the blade at the runner.

Water flows through the nozzle and enters the runner, transversely crossing the blade at the runner twice, the first is when water enters through the turbine nozzle curve. The two stages of the first stage of the water flow through the open center space (the inside of the runner) and continue through the blade behind and the bottom of the runner. Therefore this turbine is called a two level speed turbine. The portion of water that crosses the runner twice is known as cross-flow as shown in figure 4, and the name of the turbine comes from this phenomenon. There are some parts of the water that follow the blade and are thrown out of the runner, this is called entrained flow.

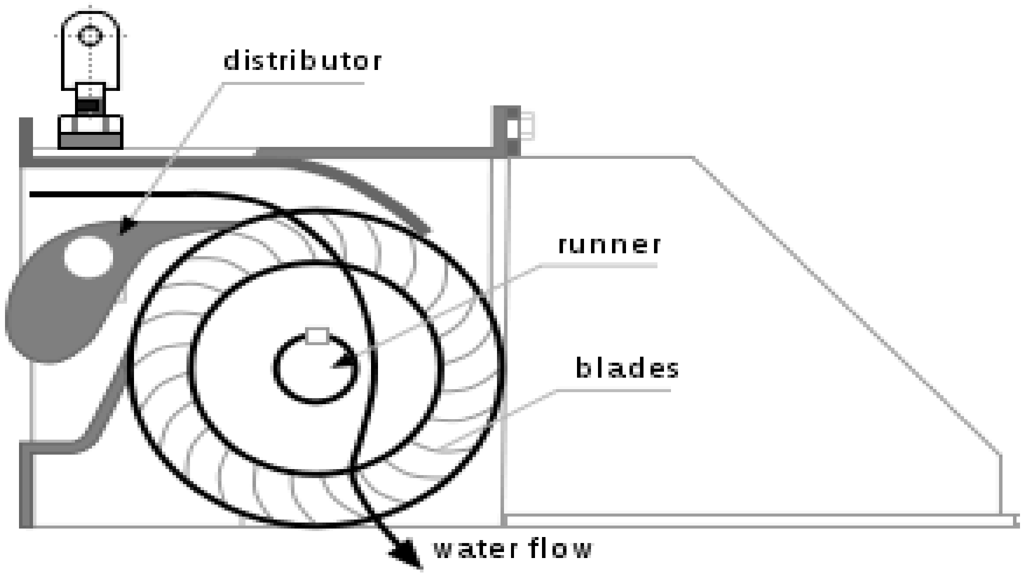

Figure 4 Cross Flow Turbine

(Source: https://images.search.yahoo.com)

The performance of micro hydro power plants with multi nozzle cross flow turbines is as follows :

1). Hydraulic Power

Hydraulic power is the power produced by water flowing from a height with the discharge of water and each head obtained through the use of measuring devices attached to the pipe [16]. Head is the energy contained by the fluid of the heavy fulide. Head is measured by using a pressure gauge, thus the head size can be obtained namely:

$Ph = H.Q.\rho.g$ (Watt) .. . (2.1)

H = head (m)

Q = water discharge (m^3/s)

ρ = density of water (kg/m^3)

g = gravitational force (m/s^2)

2). Turbine Power

Turbine power is the power generated by water turbines by changing the kinetic energy of water into mechanical energy in the form of turbine shaft rotation [17]. The amount of turbine power can be calculated using the following equation:

$$P_T = P_h . \eta_T \quad (Watt) \qquad (2.2)$$

3). Electricity Power

Electricity power is the amount of electric current flowed by the potential difference generated by an electric generator [18], which can be calculated with the following equation :

$$P_G = I . V \quad (\text{Watt}) \qquad (2.3)$$

I = Electric current (Ampere)

V = Electric potential (Volt)

2. EXPERIMENTAL SETUP

2.1. Material and equipment

- Turbine cross flow multi nozzle as a modifier water energy becomes mechanical energy driving shaft generator can be seen in Figure 5.
- The water sedative body serves as a place to collect, soothe water, settle sand, mud, filter water from sewage into the turbine, a drainage place. more water entering the turbine penstock
- Using three pipe penstock pipes AW type 3-inch PVC ", serves to drain water to the nozzle and passed on to the turbine.
- Nozzle as a means of modifying the potential energy of water into the kinetic energy of the water and directing the water to emit turbine blade
- Flowmeter, used to measure water discharge
- Tachometer to measure turbine rotation
- Voltmeter to measure the voltage
- Ampere meter to measure electric current
- Wattmeter to measure electrical power

Figure 5 Cross Flow Turbine Multi Nozzle, Generator In Power House

2.2. Methods

2.2.1. Operation Preparation

- Check the installed system installation
- Prepare the instrument properly.
- Perform calibration of measuring instruments.
- Turbine is ready to operate.
- The electric generator is ready to use

2.2.2. Operation of Micro Hydro Power Plants

- Before the turbine is operated first open the nozzle valve in the fully open position.
- After the turbine is operated, then add power to the turbine slowly until the opening position maximum turbine inlet water regulating valve.
- Measuring head, water discharge, turbine rotation,
- generator speed, electric voltage, electric current and electrical power
- Collecting data and analyzing as well recheck

3. RESULTS AND DISCUSSIONS

The application of multi-nozzle cross flow turbine as a power plant in remote areas gives good results obtained in the field with water flow capacity, high water fall (head), water power, turbine and generator rotation, voltage and current and electric power generators [19] At the research stage, through measurements for all parameters of the variables obtained based on water resources are available at the test installation and calculation process [20]. The result data of the applied specifications are the type and prototype of the multi-nozzle cross flow turbine of 3 nozzles and installed in front of the runner with a total of 24 blades, the blade angle is 30 degrees.

Then the data analysis is based on literature review and the results of the study are discussed well and the conditions and phenomena obtained that the higher the water discharge results in greater water power [21]. Then as a result of increased runner rotation, power and efficiency of cross flow turbines with multi-nozzle parallel data results of the performance of multi-nozzle cross flow turbines can be explained according to the results of the research obtained in table 4.1 shows that the lowest turbine is 313.45 Watt and generator power 257.03 Watt when the turbine uses only one nozzle with 25% valve opening, while the highest power turbine in the 5011.25 Watt or 5,011 kWatt and the maximum electric power produced by the generator is 4259.56 Watt or 4,259 kWat

This research activity is to conduct studies and analyze the determination of the right number of nozzles to produce maximum power such as micro-hydro power planning, and determine the capacity of the power produced by cross flow turbines [22]. Input data used in this study are, water discharge, water fall height, turbine torque, rotation speed and theoretical data to calculate turbine power, and compare actual turbine power with different number of nozzles [23]. Based on this data, it is found that the highest turbine power and generator power is on the use or application of a prototype Cross flow turbine with multi nozzles of three, and complete data can be seen in Table 4.1 as follows:

Table 4.1 Research Results Data

Open Valve (%)	1 Nozzle		2 Nozzle		3 Nozzle	
	P_T Watt	P_G Watt	P_T Watt	P_G Watt	P_T Watt	P_G Watt
25	313.45	257.03	585.46	480.08	905.22	742.28
50	1086.26	890.74	1716.66	1407.66	2431.93	1994.18
75	2031.38	1,665.73	2947.79	2417.19	3670.00	3119.50
100	3242.57	2,658.91	4323.43	3545.21	5011.25	4259.56

Multi-nozzle cross flow turbine is assembled from iron plate material which is processed by using several production machines in accordance with the dimensions of the design and in full can be seen in figure 6 as follows :

Figure 6 Multi Nozzle Cross Flow Turbine

Utilization of cross flow turbine by using multi nozzle is having components namely three nozzle, one runner, horizontal shaft, pully, v-shaped belt, and coupled with a 5000 Watt capacity generator with 1500 rpm rotation and in full.Turbine and the generator is installed properly in a power plant that is ready to operate [24]. This micro hydro power plant operates at a head height with a specified discharge using three stocking pipes for each of the three nozzles.

The most electric power generated by the generator when the generator uses three nozzle at full 100% valve opening, this occurs due to the maximum water discharge has a large water mass providing large energy also provides turbine rotational motion. Where before loading the turbine rotation reaches a high rotation, at the time of maximum valve opening and when there is a load or additional load with an electric generator there is a decrease in the turbine shaft rotation. So that the turbine rotation will be higher when the load on the turbine decreases. The results of testing the power generated by the turbine by comparing the generator power used can determine the efficiency of a micro hydro power system that utilizes multi-nozzle cross-flow water turbine technology [25].

The output voltage increases with increasing, with the use of multiple nozzles it is reasonable because the electric voltage is a function of rotation [26]. Generally the voltage decreases with increasing load

Figure 7 Installation of the Produced Electric Plant

In figure 7 above, it can be seen that the powerhouse has produced electric light in a functioning river basin. From the results of calculations and data analysis it can be explained that the mechanical energy of the cross-flow water turbine that has been applied as the main driver of a micro-hydro power plant is capable of producing high capacity power [27]. Then the turbine power also is very dependent on the amount of potential energy of water that can be converted into kinetic energy at the turbine nozzle. The large capacity of water out of the nozzle can have a very high speed to move the turbine blade. After hitting the blade, the flow velocity changes so that the momentum changes which causes the turbine wheel to rotate and generate mechanical power for the water turbine [28].

The advantages of applying water energy power plants are because they are sustainable and clean, energy, do not cause pollution, are easily converted to electrical energy and have a large kinetic energy intensity and do not need a structure that is too strong.

Figure 8. Power House Electric Generators

In figure 8 shows the power house generator that applies a multi-nozzle cross flow water turbine can directly convert waterfall energy to mechanical energy on the runner shaft.

Utilization of waterfall resources can be evaluated through analysis of turbine power and the power generated by electric generators [29]. The number of nozzles greatly influences the value of the increased power produced by the turbine blades entering the water. This cross flow turbine using horizontal shaft has been built with an effective and economical multi nozzle. Cross flow turbine as impulse turbine can be optimized to work at low water flow and comes from a water source then flowed towards the blade of the casing chamber to make rotational movements. The blades mounted by the runner disk wheel are made up of two round plates. The runner disk is connected by a series of blades which are shaped so that the jet of water can be directed to the center of the turbine blade and then once again crosses another blade before exiting the turbine house [30]. The jet of water then passes through the impeller and this is the origin of the name of the impeller cross-flow connected to the asynchronous generator for electricity production.

4. CONCLUSIONS

Application of multi-nozzle cross flow turbine with an external electrical power capacity of 4,250 kW. The turbines produced in this study can already be used as a support for the supply of electrical energy to the community, especially those in remote areas that are not reached by the state electricity company

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