Jurnal EKSITASI , Vol. 2, No.2, 2023
e-ISSN : 2829-5110 (online)

Design and Building a Prototype of Microhydro Gravitational Power Plant (MHGPP)

Edward Wijaya
Electrical Engineering Departement
Hasanuddin University
Makassar, Indonesia
edwardwijaya0812@gmail.com

Ansar Suyuti
Electrical Engineering Departement
Hasanuddin University
Makassar, Indonesia
asuyuti@unhas.ac.id

Fitriyanti Mayasari
Electrical Engineering Departement
Hasanuddin University
Makassar, Indonesia
fitriyantimaya@unhas.ac.id

***Abstract*— Indonesia is an archipelagic country and has abundant water sources. These water sources can be used to meet community needs, one of which is the need for electrical energy. Currently, there are still several households in Indonesia, especially in remote areas, that do not have access to electrical energy. One of the obstacles in providing electricity in remote areas is expensive construction costs. Microhydro Gravitational power Generation Technology (MHGPP) is a technology that generates electrical energy using hydropower. MHGPP has simple and cheap construction, so it can be used to overcome electricity problems in Indonesia, especially in remote areas that have abundant water sources. This research aims to create a flow of water from a calm water source by using a tool, namely a pump that works with gravity, and then utilizing the water flow from the gravity pump to produce electrical energy. Furthermore, this research also aims to find out the type of generator that is suitable for use as a prototype or initial design of a MHGPP. Based on the research results, it is known that the prototype has succeeded in creating a water flow with a water flow of 0.2 liters/second. The prototype of the MHGPP has also succeeded in spinning the turbine at a speed of 83 RPM and then produces an output voltage that is sufficient to make the load which is a lamp (6 Volt, 8 Watt DC lamp) light up even though it is dim. The generator that is suitable for the MHGPP prototype is a low RPM generator which can produce a large output voltage for a small rotation.**

Keywords—Renewable Energy, Hydropower, Prototype, MHGPP

I. INTRODUCTION

Development of renewable energy is very necessary in Indonesia, especially in the electricity sector to achieve the energy mix target by 2025.

Indonesia is a maritime country and is known to have abundant springs. The abundant springs in Indonesia can be utilized to meet people's needs, one of which is the need for electrical energy.

Currently there are still several regions in Indonesia that have not received electrical energy supplies. The national electrification ratio in Indonesia in 2022 will reach 99.63% [1]. Based on this data, it can be seen that there are still 0.37% of households in Indonesia that do not have access to electrical energy. One of the obstacles that makes it difficult to provide electricity in several regions of Indonesia, especially in remote areas, is due to expensive construction costs.

Microhydro Gravitational power Generation Technology (MJGPP) is a technology that can be used to generate electrical energy using hydropower. Gravity microhydro technology utilizes the potential of water in an area and is used to drive turbines to produce electricity.

Because it has a construction that is easy to make, cheap, and can also generate electrical energy using water, this research, namely "Design of a Microhydro Gravitational Power Plant Prototype (MHGPP)" is proposed. This research, apart from being able to support the development of renewable energy in Indonesia, can also overcome electricity problems in Indonesia, especially for remote areas that have abundant water sources..

II. LITERATURE REVIEW

A. Bernoulli's Law

Bernoulli's law is an application of natural law discovered by a mathematician from Switzerland, namely Daniel Bernoulli (1700-1782). Bernoulli's concept has the same concept as work and energy. Bernoulli formulated an equation that explains the relationship or connection between kinetic energy, potential energy and pressure [2].

This relationship can be explained through a water flow that flows through a pipe with a non-uniform cross-sectional area and is located at a different height from a certain reference point. Based on Figure 1, it can be seen that a fluid flows through the larger cross-section of point 1 (A_1) and goes to point 2 (A_2) which has a small surface area. The fluid flows at speed V_1 and exits at speed V_2. Based on the fluid continuity rule which states that, when the surface area is large then the speed will be low, and when the cross-sectional area is narrow, the speed will be increased.

Furthermore, based on Figure 1, the height at point 1 relative to the ground surface, symbolized by y_1, is lower than point 2 or y_2. So the potential energy at y_1 will be smaller than y_2.

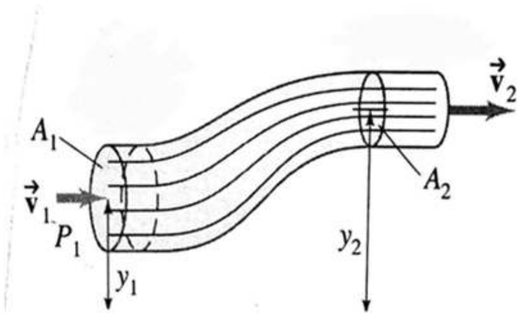

Fig. 1 Bernoulli's Law [3]

It can be proven through an equation called the Bernoulli equation, as given in Equation (1).

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2 \quad (1)$$

Where:

P = Pressure (Pa)

ρ = Density (kg/m^3)

v = Speed (m/s)

g = Gravity (9,8 m/s^2)

y = Height (m)

B. Water Siphon

A water siphon is a way to move liquid from one container to another without using tools.

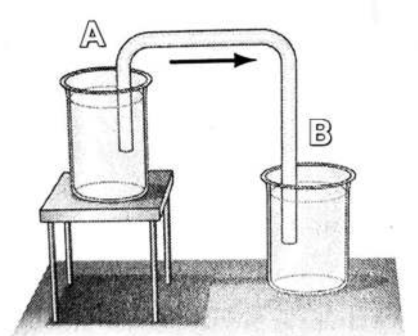

Fig. 2 Siphon System

Water siphon/siphoning can work because of the height and also the pressure difference in the inlet pipe and output pipe [2].

The pressure at the surface of a liquid is atmospheric pressure. When the exit tube (B) has a surface pressure that is below the surface pressure of the liquid in the input tube (A), this difference will encourage water to flow and move from the input container to the output container. The pressure that causes a water siphon to occur is atmospheric pressure/ air.

C. Fluid Pressure and Atmospheric Pressure

Fluids have pressure. Fluids exert pressure in all directions. This can be felt when humans swim or dive, where when in water humans can feel the water pressing on the entire human body from all directions. The pressure on the fluid has the same magnitude in all directions in in the fluid at a certain depth, if the fluid does not have the same pressure in all directions then the fluid can certainly move/flow [3]. Pressure on a fluid can be formulated by the equation:

$$P = \rho \cdot g \cdot \Delta h \quad (2)$$

From this equation it can be seen that the pressure in a fluid is directly proportional to the density of the fluid and is also directly proportional to the depth of the location of the object point in the fluid.

Earth's atmospheric pressure / air pressure also changes according to height from the Earth's surface. The higher a place, the air pressure at that place tends to be lower. Earth's atmospheric pressure is the pressure exerted on every object on earth, including humans. The average atmospheric pressure is 1 atm (atmosphere) = 1.013 x 105 N/m2 = 101.3 kPa [3].

Atmospheric pressure exerts pressure on every object that comes into contact with it, including liquid objects. Atmospheric pressure is the pressure that causes suction to occur, where the pump's suction concept is: The pump functions to reduce the pressure at the top of the tube and will cause atmospheric pressure to push the water up in the tube when the top of the tube has low pressure (vacuum) [4].

D. Hydroelectric Power Plant

A hydroelectric power plant is an electricity plant that uses water power (primary energy) as its main energy source. Based on the classification of energy sources, hydroelectric power plants are included in the type of renewable power generation.

Hydroelectric power has a working principle by utilizing potential energy produced by water pressure which tends to always flow from high to low pressure. The potential energy from the water is then used to rotate the turbine to produce mechanical energy. The mechanical energy from the turbine is then channeled to the generator through the shaft to produce electrical energy [5].

Hydroelectric power plants can be classified based on their power or generation capacity. Based on the amount of power produced, hydroelectric power plants are classified into 5 types, namely Picohydro hydroelectric power (< 0.5kW); Microhydro Hydroelectric Power Plant (0.5-100kW); Minihydro Hydroelectric Power Plant (100mW-1000kW); Small Scale Hydropower; (1 mW-10mW) and Large Scale Hydroelectric Power (> 10mW) [6].

E. Water Turbine

A water turbine is a component that will rotate when a water flow passes at high speed. The water turbine is a component that is connected/coupled to the generator, so that when the turbine rotates, mechanical energy is produced by the turbine. Water turbines are generally used in power plants that use hydropower (PLTA and PLTMH).

Based on the working principle, water turbines are divided into 2 groups.

1. Impulse turbine: is a turbine that is made in such a way that the runner works due to the flow of water. In an impulse turbine, kinetic energy or water flow speed is caused by potential energy or height differences. An example of an impulse turbine is the Pelton turbine.
2. Reaction turbine: is a turbine where the rotor works due to the flow of water with a height drop due to pressure. Reaction turbines are generally used for hydropower or PLTMH locations with low heads but large water discharges. Included in the reaction turbine types are Francis turbines, diagonal flow turbines, and propeller turbines [7].

F. Synchronous Generator

A synchronous generator is a very important device and is widely used in human life. Synchronous generators are divided into two types based on how they provide flux or how they produce a magnetic field in the coil. Synchronous generators can be grouped into independent gain generators, self-gain generators and compound generators [8]

There are 3 things that need to be considered in a generator so that it can produce electrical energy, namely rotation, coil, and electromagnetic force.

G. Microhydro Power Plant

Microhydro Power Plant is a hydroelectric power plant with a capacity of 0.5 kW to 100 kW. Microhydro power plant consists of 3 main components, namely water (water flow); turbine; and generators. The working principle of microhydro power plant is simple: the turbine will be rotated by a water flow that comes from nature to produce mechanical energy. The water flow can be in the form of river flows and irrigation canals. The turbine at the microhydro power plant can also be rotated through a stream of water that falls based on height/potential like a natural waterfall. The mechanical energy from the turbine will then be used to drive the generator. The generator will then convert the mechanical energy from the turbine into electrical energy [10].

H. Micro Hydro Gravitational power Plant (MHGPT)

Microhydro Gravitational power Plant (MHGPT) is a type of hydroelectric power plant where the energy source also comes from hydropower.

The main difference between microhydro power plant and microhydro gravitational power plant lies in the components of the generator. Microhydro power plant consists of water flow (from nature), water turbine and generator, while microhydro gravitational power plant consists of 3 components, namely a gravity pump, water turbine and generator.

Based on the components of the microhydro gravitational power plant , it can be seen that the microhydro power plant gets its water flow from nature, and the microhydro gravitational power plant gets its water flow from a gravity pump. Microhydro gravitational power plant can be used to overcome the problems/disadvantages of micro hydro power plants because the water flow from microhydro gravitational power plant does not depend on natural water flow. In this way, microhydro gravitational power plant can still provide stable output even during the dry season.

III. Research Method

A. Microhydro Gravitational power Plant Design

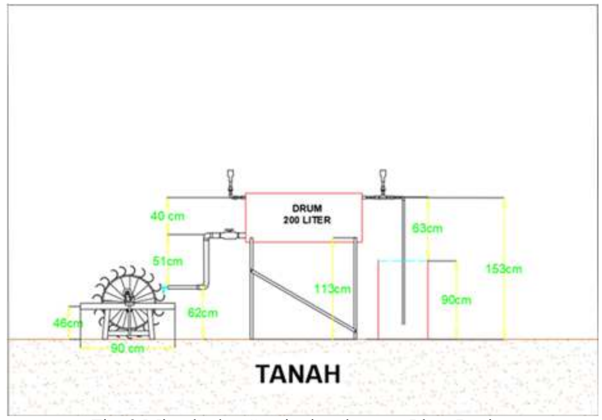

Fig. 3 Microhydro Gravitational power Plant Design

B. Research Tools and Materials

- Tools: Tachometer, Laptop, Autocad Multimeter Software, Stopwatch, Measuring Meter, Saw, Pipe Wrench, Screwdriver, Pliers, Ring Wrench, 19 liter gallon
- Materials: 20 liter iron drum, bicycle vleg, generator, PVC pipe, stop faucet, iron frame for drum, iron frame for turbine, pipe connection, PVC pipe glue, valve clamp, pressure gauge, screws, 27 teeth gear, 6 volt lamp DC 8 watts

C. Research Procedure

Figure 4 shows the flowchart diagram of the research. It can be seen from the chart, that the research procedure can be written as follows:

1. Build a MHGPP component consisting of a gravity pump and water turbine coupled to a generator.
2. Create a gravity pump vacuum. This is done by completely filling the gravity pump (drum) using water.
3. Open the tap on the output pipe and check whether the water at the source is decreasing or not.
4. The water in the output pipe is then used to spin a turbine which is coupled to a generator to produce electrical energy

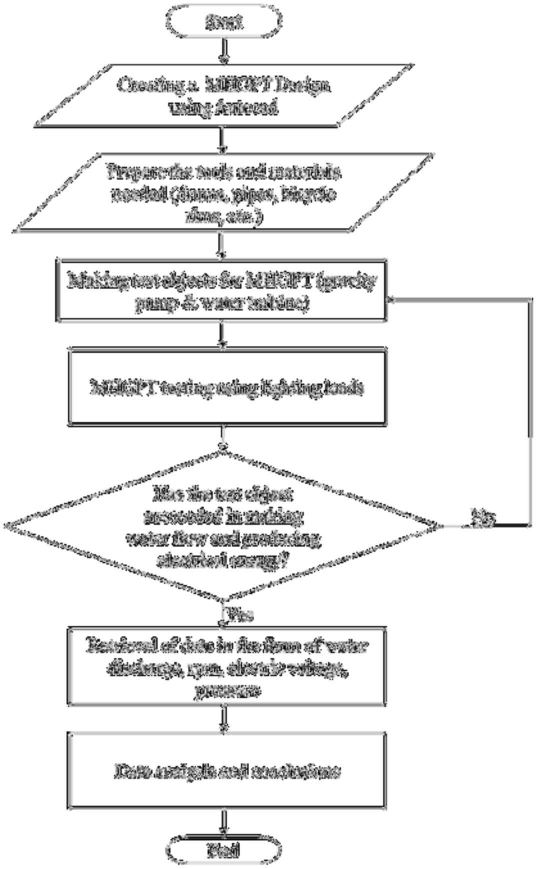

Fig. 4 Research Flow Diagram

IV. Result and Analysis

A. Physical form of the object

Figure 5 gives the prototype form of the designed microhydro gravitational power plant.

Fig. 5 Prototype form of the Microhydro Gravitational Power Plant

B. Water Discharge Test Results

Water discharge test on prototype is done by using a 19 liter gallon and a stopwatch as seen in Figure 6. The prototype of the MHGPP takes 1 minute 30 seconds to fill a 19 liter gallon, so based on the water discharge formula, a discharge of 0.2 liters/second is obtained.

Fig. 6 Water Discharge Test

Fig. 7 RPM Testing

C. RPM Test Results

RPM testing is carried out using a tachometer (seen in Figure 7). In the no load condition, an RPM of 109 to 110 RPM is obtained. Testing the RPM in the second condition, namely by using a lighting load in the form of a 6 Volt, 8 Watt DC lamp, obtained an RPM of 79 to 83 RPM

D. Voltage Test Results

Voltage test on prototype is done by using a multimeter as in Figure 8. The results of the voltage test in the no load condition, obtained a voltage of 5.7 Volts. Next, in the second condition, namely measuring the voltage with the generator output connected to a load in the form of a 6 Volt, 8 Watt DC lamp, a voltage of 3 volts DC is obtained.

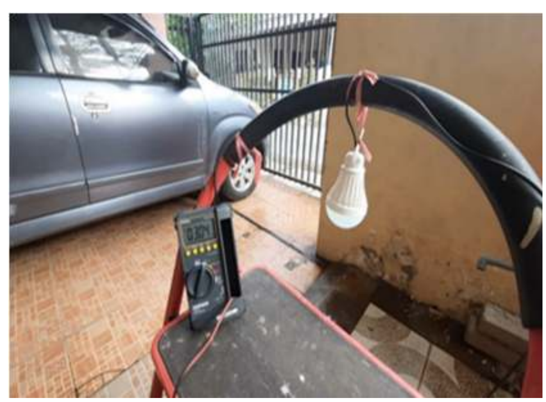

Fig. 8 Voltage Testing

E. Calculation of Pressure in Pipes

Pressure calculations are carried out using the Bernoulli formula according to equation (1). First step is to determine two points, where on the input pipe, point 1 and point 2 can be seen in Figure 9.

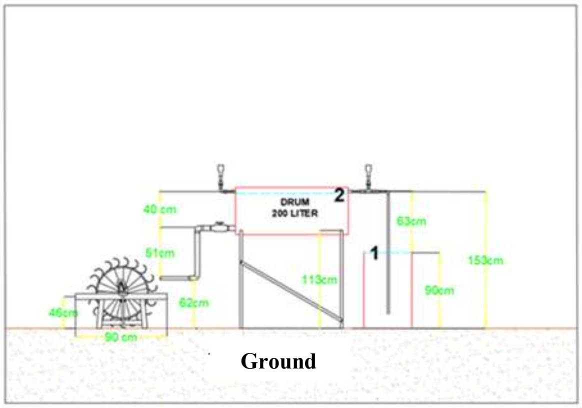

Fig. 9 Pressure Calculation on Input Pipe

Next step is to determine the point of the output pipe. The point of the output pipe can be seen in Figure 10.

Based on pressure calculations using the Bernoulli formula, the pressure obtained in the input pipe is 6,174 Pa. Meanwhile, the pressure in the output pipe is 8,918 Pa

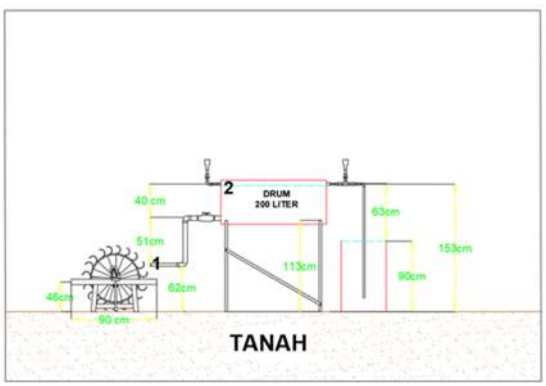

Fig. 10 Pressure Calculation on Output Pipe

F. Result Analysis

Based on the research results, it is known that the prototype of the MHGPP has succeeded in moving water from the source. This is because the pressure in the output pipe is greater than the input pipe, so that when the water tap on the output pipe is opened, water will tend to flow into the output pipe and then an air gap will arise which will draw water from the input pipe/spring source in accordance with siphon system.

The prototype of the MHGPP has also succeeded in producing mechanical energy and rotating the turbine with an RPM of 110 RPM in the no-load condition, and obtained an RPM of 83 RPM in the loaded condition.

The prototype of the MHGPP has succeeded in producing an output voltage of 5 Volts in the no-load condition. Furthermore, when it is connected to a load (6 Volt, 8 Watt DC lamp), a lower voltage is obtained, namely 3 Volts. This is caused by an armature reaction that occurs in the armature coil or stator, causing an opposing magnetic field which makes the turbine rotation slow down and the generator voltage output becomes low.

V. CONLUSIONS

Based on the experiment, water flow can be created from still springs using a gravity pump which works based on vacuum pressure and gravity. Gravity pumps can be made using simple materials, namely drums and water pipes. Obtained water discharge of 0.2 liters/second.

Testing the turbine rotation speed and output voltage of the MHGPP at no load, the rotation speed ranges from 109 – 110 RPM and the voltage is 5.7 volts. While under load (i.e. one 6 volt DC, 8 watt lamp) the turbine rotation speed is 79 – 83 RPM and the MHGPP output voltage is 3 volts DC, in this condition the load (light) is on but dim.

Based on pressure calculations, the results obtained are that the pressure in the output pipe is greater than the input pipe. This condition causes water to tend to flow through the output pipe and then the greater pressure in the output pipe will also cause the water to rise through the input/source pipe.

REFERENCES

[1] PT PLN (Persero), 2023, Statistik PLN 2022, Sekretariat Perusahaan PT. PLN (Persero)

[2] Y.A. Cengel, J.M.Cimbala. 2006. Fluid Mechanics Fundamental And Aplication.New York : The McGraw-Hill Companies

[3] D.C. Giancoli. 2014. Fisika Edisi Ketujuh Jilid 1.Jakarta : Erlangga

[4] M.White, Frank. 2011. Fluid Mechanics Seventh Edition.New York : The McGraw-Hill Companies

[5] Hidayat. 2017. Mikrohidro. Padang : Bung Hatta University Press

[6] P.N. Yuniarti, Ilham Wisnu Aji. 2019. Modul Pembelajaran Pembangkit Tenaga Listrik.Yogyakarta :Universitas Negeri Yogyakarta

[7] A. Arismunandar, S. Kuwahara. 2004. Buku Pegangan Teknik Tenaga Listrik. Jakarta : PT Pradya Paramita

[8] Anonim. 2003, Panduan Untuk Pembangunan Pembangkit Listrik Mikro-hidro Penerbit : Departemen Energi dan Sumber Daya Mineral Republik Indonesia

[9] Zuhal. (1988). Dasar Teknik Tenaga Listrik Dan Elektronika Daya. Jakarta : PT Gramedia

[10] Purwanto.2017.Pembangkit Listrik Mikrohidro (PLTMH) Sebuah Pilihan : Belajar dari Koperasi Mekar Sari , Subang.Jakarta : LIPI Press