Design and Construction Of a Small-Scale Permanen Magnet Micro-Hydro Power Plant in Kunigan West Java

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Abstract— **Electricity is a vital necessity for the community, particularly in remote areas not yet adequately served by the electricity grid. One form of renewable energy with significant development potential is hydropower, utilised through Micro-Hydropower Plants (MHPs). Kuningan Regency possesses substantial hydropower potential via the Cisanggarung River, with an average flow rate of approximately ±100 litres per second, based on data from the Baok and Cibinuang monitoring stations. The flow of the Cisanggarung River then flows into and empties into the Cigintung River, which is the location of this study; consequently, the conditions and characteristics of the water flow in the Cigintung River are also influenced by the flow rate of the Cisanggarung River. This small hydroelectric power plant (PLTMH) system is designed to utilise the kinetic energy of the water to rotate a turbine, which is then converted into electrical energy using a permanent magnet generator. The research methods included a site survey, the design of the turbine and power generation system, and performance testing. A permanent magnet generator was chosen due to its high efficiency and the fact that it does not require an additional excitation current, with a diode rectifier system and a 1000 µF/50V capacitor to stabilise the DC voltage. Test results show a voltage of 23 V DC and 2834 RPM under no-load conditions, and 11.5 V DC, 0.70 A current, and 1754 RPM when loaded with one 12 V DC lamp (5 W) and two 12 V DC lamps (10 W). The electrical energy generated is intended for use in small-scale applications such as lighting, making it a potential alternative energy solution in rural areas.**

Keywords— ***Micro-hydro power plant*** **(PLTMH),** ***Permanent magnet generator*** **(PMG),** ***Kaplan turbine, River flow rate, DC voltage, Energy conversion system***.

I. INTRODUCTION

Permanent magnet generators are energy converters used to generate electrical power by converting mechanical energy into electrical energy via electric and magnetic fields. The mechanical energy input to the generator is derived from various driving forces, such as wind, water and steam. Various types of power stations are used to generate electrical energy [1]. The application of (PMG) is one approach to maximising power conversion in hydroelectric power systems (PLTA), which typically operate at low speeds. These generators operate by optimising the magnetic field generated by permanent magnets, until

requires an external excitation source, such as that found in an asynchronous generator [2]. The key advantage of this permanent magnet generator is that it does not use copper wire windings to generate a magnetic field, unlike conventional generators [3]. Neodymium permanent magnets are more commonly used in generators, as they are stronger and more durable than standard magnets [4].

Permanent Magnet Synchronous Generators (PMSGs) and Double-Fed Induction Generators (DFIGs) are the most commonly used in wind turbines [5]. A synchronous generator that uses permanent magnets on its rotor to generate magnetic power, rather than excitation windings. The Permanent Magnet Synchronous Generator (PMSG) is a product of modern innovation in power generation technology. This type of generator is most widely used for converting small-scale mechanical power into renewable energy. [6]. In order to generate a higher output voltage at low speeds, various measures can be taken, including increasing the number of poles, increasing the number of stator conductors, and increasing the number of stator and rotor laminations [7].

Permanent Magnet Synchronous Generator (PMSG) consists of an armature winding, formed from a series of wire coils wound around the stator teeth [8]. The permanent magnets generate a magnetic field that moves the windings to produce an induced current [9]. The flux in a permanent magnet generator (PMG) generates electrical power with the direction of the flux flow perpendicular to the windings [10]. One type of permanent magnet is neodymium, known as NdFeB, NIB, or Neo-magnet [11]. Therefore, a permanent magnet generator is the more appropriate choice [12].

When using a permanent magnet generator, also known as a synchronous generator, it is expected to produce a higher voltage output [13]. A synchronous generator, or an electric machine that converts mechanical power into electrical power, operates such that the RPM (rotor speed) is always synchronous (equal) with the speed of the magnetic field in the stator, thereby generating electrical energy [14]. The Kaplan turbine is driven by water entering through a penstock pipe in the power generation chamber. This generates mechanical energy through the rotation of the turbine shaft; this rotation then drives the generator, which produces electrical energy [15]. A micro-hydro power generation system consists of three main components: technically, these three components are water (as a source of kinetic energy), the turbine, and the generator [16].

Kuningan Regency possesses sufficient water resources, particularly at the foot of Mount Ciremai, which can be utilised as a source of electrical energy. Consequently, this study aims to design and develop a system. As an alternative energy source for the local community, the micro-hydro power plant utilises a permanent magnet generator.

II. MATERIALS AND METHODS

This study employs design and experimental methods to design and test a micro-hydro power generation system (PLTMH) utilising a permanent magnet generator. The research stages were carried out systematically, from site surveys to testing of the power generation system.

This study was conducted in Kuningan Regency, West Java, and focused on small-scale water energy sources that can be used to develop a Micro-Hydro Power Plant (PLTMH) based on a permanent magnet generator. The location was selected based on the availability of a sufficiently stable water flow and the need for an efficient and sustainable electricity supply to support the use of renewable energy sources in the area.

A. HYDROPOWER GENERATION SYSTEM

Comprises the following main components:

1. The Kaplan turbine is the most popular type of water turbine as it is suitable for a wide range of flow rates and head heights, and offers good efficiency under various flow conditions. Small turbines, typically under 10 MW, have a horizontal shaft, although they are sometimes also used for capacities of up to 100 MW [17]. To optimise the efficiency of the energy converter, the turbine dimensions are adapted to the characteristics of the river flow.
2. The power plant utilises a magneto-wound generator with the code (5 TL). This generator was selected because it offers higher efficiency and does not require an external excitation source, making it suitable for small-scale power generation systems.

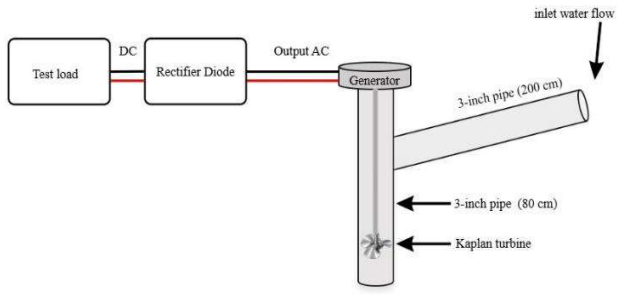


Fig 1. Schematic of a small-scale hydroelectric power plant

In Fig 1 above, a design for a hydroelectric power plant featuring a Kaplan turbine model can be seen. The following is an explanation of this hydroelectric power plant:

1. A penstock (rapid pipe) is used as the water inlet and utilises a 3-inch pipe connected to a 3-inch T-joint.
2. A T-pipe fitting used to connect the flexible pipe to a 3-inch T-pipe fitting.
3. A 12 mm iron rod inserted into the pipe and connected to the 40 cm-long magnetic coil generator to rotate the magnet and generate electricity.
4. A Kaplan turbine connected to the end of the 12 mm shaft to rotate the magnetic coil.
5. A 3-inch pipe cap serving as the generator mount.
6. The electricity produced by the generator is rectified using a diode and fed directly to a 12-volt DC lamp.

B. DATA PROCESSING AND ANALYSIS

Data processing and analysis begin by reviewing the design concepts of the micro-hydro power plant (PLTMH), then testing the performance quality of the equipment, and finally calculating the ideal values using mathematical formulas.

C. SYSTEM BLOCK DIAGRAM

This is a graphical visual representation that uses geometric shapes (blocks) to depict the components, functions, or main stages within a system, as well as arrows to indicate signal flow or the relationships between components. The block diagram is used to illustrate the overall workflow of the micro-hydro power plant system, as follows:

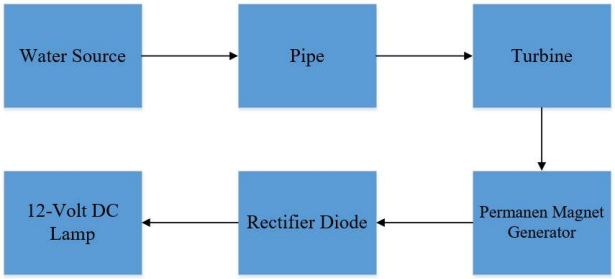


Fig. 2. Block diagram of the equipment design process

The block diagram of the equipment design includes the following:

1. Water channel. This is the primary energy source in the small hydroelectric power plant system. Moving water possesses kinetic energy which is utilised to rotate the turbine.
2. Pipe. This functions as a conduit to direct the flow of water from the source to the turbine. These pipes also help to maximise the pressure and velocity of the water flow to ensure optimal performance when it strikes the turbine.
3. Turbine. This converts the kinetic energy of the water into mechanical energy in the form of rotation. This rotation is then transmitted directly to the generator.
4. Permanent magnet generator. This converts the mechanical power from the turbine into electrical power. This generator is chosen because it has high efficiency and does not require an additional excitation source.
5. Rectifier diodes. This component serves to convert the alternating current (AC) output from the generator; it is rectified by the rectifier diodes and

the output is converted into direct current (DC), so that it can be used for DC loads.

6. 12-volt DC lamp. This acts as a load within the system, utilising the electrical energy produced by the conversion. This lamp serves as an indicator that the system is operating and generating electrical energy.

D. *EQUIPMENT TESTING*

a series of tests were carried out on the power plant. These tests involved observing and recording the data displayed on the measuring instruments [18]. The tests were conducted to evaluate the performance of the small-scale hydroelectric power generation system using the following parameters:

1. The water flow rate can be calculated using the following equation:

$$Q = V/t \text{.....(1)}$$

Where:

Q = water flow rate expressed in cubic metres per second (m^3/s)

V = water volume in cubic metres (m^3)

t = time in seconds

2. Rotational speed (RPM)
3. Voltage (Volts)
4. Current (I)
5. Electrical power (Watts)



Fig. 3. Final result of the micro-hydro power plant construction

The calculation of electrical power uses the following formula:

$$P = V.I \text{.....(2)}$$

Where:

P = Power in watts

V = Voltage in volts

I = Current in amperes

III. RESULTS AND DISCUSSION

This study was conducted in Indapatra Village, Kuningan Regency, West Java. The water source is the Cigintung River in Kuningan Regency, which has a flow rate of 3 to 6 litres per second. Based on the needs for utilising this river, it is used by local residents throughout the River Basin Area (RBA) for daily needs, including irrigating rice fields, fish farming, and plantations.

From this micro-hydro power plant (PLTMH) development model, experimental results and on-site calculations were obtained. Data collection was carried out for the first experiment at 08:00 WIB, the second at 11:00 WIB, the third at 13:00 WIB, the fourth at 15:00 WIB, and the fifth at 17:00 WIB. This was conducted from day 1 to day 7, yielding 5 experimental results per day. Details of the micro-hydro power plant can be seen in Table 1

Table 1. Specifications of the micro-hydro power plant equipment

Equipment details	**Description**
High-pressure pipe (3 inches)	200 cm
Kaplan turbine	7,33 cm
Generator type	Coil, permanent magnet
Comb diode	25 amperes
Capacitor	1000 µF/50V
Test load	12-volt lamp DC
Output system	DC

Based on the design specifications of the Small-Scale Hydroelectric Power Plant (PLTMH) under test, the following data were obtained: water flow rate (litres per second), shaft speed (RPM), voltage (volts), current (amperes) and power (watts), as shown in Table 2 below.

Table 2: Average values from the test results

Day	Flow rate m^3/s	RPM	Voltage (V)	Current (I)	Power (W)
Day 1	5,4	1878	11,56	0,728	8,4168
Day 2	4,8	1.653,50	9	0,24	1,5034
Day 3	5,4	1.356,80	11,36	0,694	7,901
Day 4	3,6	1.153,60	11,54	0,682	8,4958
Day 5	5,4	1.301,40	11,54	0,502	5,3362
Day 6	4,8	1.535,00	11,54	0,71	8,1934
Day 7	4,8	1.026,80	10,06	0,422	4,253

Based on Table 2, the data collected at this site is intended to observe changes in the performance of small-scale hydroelectric power stations in response to the time of data collection. This is due to fluctuations in water flow velocity, which result in varying data patterns. With fluctuating water flow rates, measurements of the shaft rotation speed (RPM) over time undergo significant changes, thereby affecting the measured voltage (V) and current (A) values.

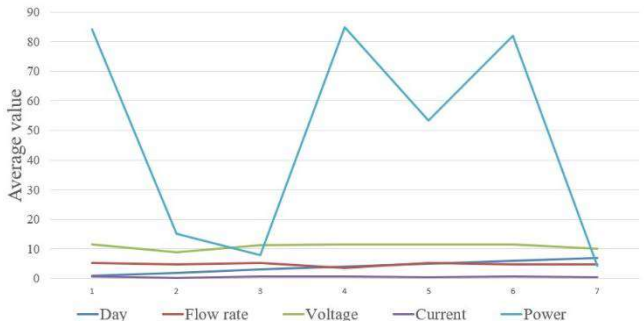


Fig. 4. Graph of average data

As shown in Fig. 4, test results under different conditions and at different times indicate that variations in water flow affect the voltage (volts), current (amperes) and power (watts) output by the small hydroelectric power system. Power values tend to increase when water flow and current are higher, although the voltage remains relatively stable. The highest power output of 8.4958 watts occurred on day 4 with a flow rate of 3.6 and a current of 0.682 A, whilst the lowest power output occurred on day 2 at 1.5034 watts. This indicates that the combination of water flow rate and current significantly influences the magnitude of the power output.

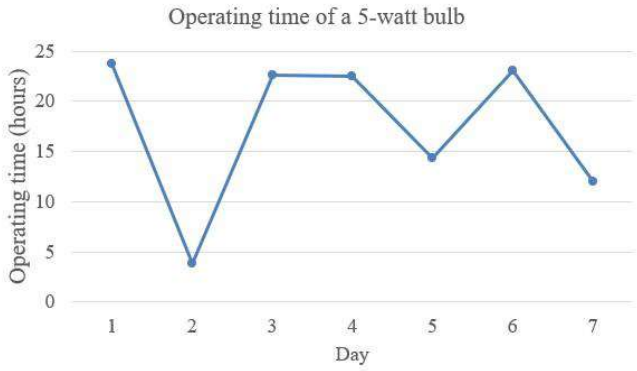


Fig. 5. Operating time of a 5-watt lamp per day

Fig. 5 shows the relationship between the test day and the operating time of a 5-watt lamp powered by a micro-hydro power generation system (PLTMH). Data collected over 7 days reveal fluctuations in the lamp's operating time, influenced by water flow conditions and the performance of the power generation system.

On day 1, the lamp's operating time reached approximately 24 hours. However, on day 2, there was a significant drop to around 4 hours. Subsequently, on days 3 and 4, the lamp's operating time increased again to around 22–23 hours. On day 5, the operating time decreased to around 14 hours. On day 6, the operating time increased again to around 23 hours, indicating that the system's performance had improved. Meanwhile, on day 7, the operating time fell to around 12 hours, demonstrating that variations in environmental conditions affect the performance of the PLTMH.

Overall, small-scale hydroelectric power systems are capable of generating electricity to meet small-scale lighting needs, but their performance is still affected by unstable water flow conditions.

Based on the findings of my research entitled 'Design and Construction of a Small-Scale Permanent Magnet Micro-Hydropower Plant (PLTMH) in Kuningan, West Java'. This research differs from previous studies in its approach to the design and implementation of small-scale PLTMHs tailored to the water resource conditions in Kuningan Regency, West Java. Unlike previous studies, which generally utilised moderate to high water flow rates, my research specifically utilises low water flow rates ranging from 3–6 litres per second, which are commonly found in small rivers, particularly in rural areas.

Furthermore, the uniqueness of this study lies in the use of a simple permanent magnet generator (5 TL magnetic coils), which is more economical and readily available compared to specialised generators such as axial-flux permanent magnet generators, which have generally been used in previous studies. This system is designed using a direct coupling method between the Kaplan turbine and the generator without a gearbox, thereby improving mechanical efficiency and simplifying the construction of the equipment.

In terms of electrical output, this research produces a DC voltage. Whilst the output from the magnetic coil is initially an AC voltage, it is rectified by a diode rectifier circuit and an electrolytic capacitor to stabilise the voltage, and can be used directly to power simple loads such as a 12-volt DC lamp.

Another innovation lies in the testing method, which was conducted directly in the field with data collection over a period of 7 days across 5 experiments, thereby accurately representing real-world conditions of water flow fluctuations and system performance. This research focuses not only on the design aspect but also on practical implementation as a simple, efficient, and sustainable alternative energy solution for rural communities.

IV. Conclusion

Based on the results of my research, it is clear that a micro-hydro power generation system (PLTMH) based on a permanent magnet generator (PMG) has been successfully designed and implemented. This system is capable of producing a voltage of 23 V DC under no-load conditions and 11.5 V DC under load conditions.

The electricity generated is sufficient to meet small-scale needs such as lighting. The system's performance is influenced by water flow velocity, load, and the efficiency of the components used. Permanent magnet generators have proven effective in PLTMH systems due to their high efficiency and the fact that they do not require additional excitation. Therefore, this system has the potential to serve as an environmentally friendly and more economical electricity solution for communities in remote areas.

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