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Pico Hydro Generation System for Building's Supplementary Energy

(Sistem Penjanaan Piko Hidro untuk Tenaga Tambahan Bangunan)

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ABSTRACT

Renewable energy is an important source in supplying energy to the masses as it is sustainable, environmentally friendly, and require less maintenance cost compared to the conventional fossil fuel resources. This paper describes the study of a pico hydro generation system. The power generation system uses water utilized by a building as the source to generate energy. In the study, the system prototype is designed using several combinations of piping system where different sizes, shapes, and turbine positions are used. The energy from the water flowing through the piping system will be converted into electrical energy through the turbine system that is placed in the main water tank. The best combination of pipeline system for the prototype is by using two different positions of water jet. This combination requires lower water pressure and is able to generate 198 W of energy.

Keywords: Pico hydro generation system; renewable energy

ABSTRAK

Tenaga boleh diperbaharui adalah sumber penting dalam pembekalan tenaga kerana ia ialah sumber lestari, mesra alam, dan memerlukan kos penyelenggaraan yang lebih rendah berbanding sumber bahan bakar fosil yang konvensional. Makalah ini menerangkan kajian mengenai sistem penjanaan piko hidro. Sistem penjanaan tenaga di dalam makalah ini menggunakan air yang digunakan oleh bangunan sebagai sumber untuk menjana tenaga. Dalam kajian ini, prototaip sistem direka menggunakan beberapa kombinasi sistem perpaipan di mana ukuran, bentuk, dan kedudukan turbin yang berbeza digunakan. Tenaga dari air yang mengalir melalui sistem perpaipan akan diubah menjadi tenaga elektrik melalui sistem turbin yang diletakkan di dalam tangki air utama. Kombinasi terbaik sistem paip untuk prototaip adalah dengan menggunakan dua kedudukan jet air yang berbeza. Gabungan ini memerlukan tekanan air yang lebih rendah dan mampu menghasilkan 198 W tenaga.

Kata kunci: Sistem penjanaan piko hidro; tenaga boleh diperbaharui

INTRODUCTION

Nowadays, water is becoming one of the important sources to generate energy. The use of renewable energy can reduce the environmental pollution and, in the process, may save a lot of money. In electrical power generation industry, water is used to generate electrical power through hydroelectric system. But, the process of generating energy through hydroelectric system causes environmental pollution and harm living things. This normally happens near river or reservoir area where they are turned into huge dams. Besides being very costly, the system has potential in causing major environmental damage such as flood and landslide to nearby areas. All of the huge dam power generation stations need a very large quantity of water to complete the water flow system (Vineet et al. 2017; Martina et al. 2018; Anabela et al. 2016; M.D. Bejarano et al. 2019).

In Malaysia, there are several water dams to generate electrical power. The process of building these dams have caused the reduction of clean water source and reservoir space (Wan Syakirah Wan Abdullah et al. 2019). Thus, the pico hydro generation system is introduced as one of the system which produces electricity without harming the environment and at the same time considered as a renewable energy. This is because the installation process of the system does not need water from a dam. It is a simple system which only needs pipeline, turbine, and generator system (Marco 2015; Akhilesh et al. 2015). The pico hydro generation system can be used as a supplementary power source to the user. It is able to generate electrical power up to 198 W and can be used as a backup to the main electrical supply. This study utilized domestic water in the main water tank as a prime mover in order to turn the turbine of generator. The water that has been used may be recycled in the water tank for other usage.

PIPING SYSTEM

Figure 1 shows the flow of energy conversion involved throughout the piping system. The potential energy depends on the mass of water that is located at a higher elevation. When the location of water source is at a higher elevation, more potential energy will be obtained. From the potential energy, water pressure will be formed through the pipeline and known as kinetic energy. This is depending on how the water flows at higher elevation. At this stage, the design of pipeline in terms of size and shape is important because it will give a high impact on the kinetic energy (Eva Gomez-Llanos et al. 2018). Then, the mechanical energy will be generated through the kinetic energy of water by hitting the turbine which will rotate the blade. This is important to form an effective rotation of turbine.

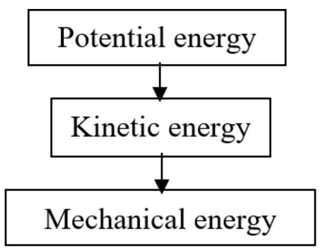


FIGURE 1. Energy conversion process

TURBINE

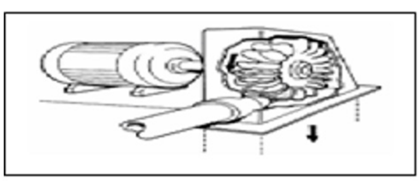


FIGURE 2. Turbine system.

Turbine system is one of important part in micro hydro power plant (Bilal Abdullah Nasir 2014). Figure 2 shows the turbine system. The effectiveness of the turbine depends on the location it is set along the pipeline. Generally, turbine can be classified into two categories which are impulse turbine and reaction turbine. Both types of turbine are able to generate electrical energy through different methods. Impulse turbine operates on high to medium head with free-jets and ventilated tailraces. Reaction turbine operates on medium to low head. The turbine is placed directly in the water stream and the speed of the blades rotating depends on the combination of pressure and moving water.

GENERATOR

AC generator is a type of induction machine commonly used in generating power in Micro Hydro Power Plant. It consists of two important parts which are fixed wound stator core and rotor that rotates in the center of the core.

The generator will operate when there is an external force applied to the rotor. Once the rotor is rotating, rotating magnetic field will be created inside the machine. The rotating magnetic field produced will react with stator in order to magnetize current through the coil. The current will be induced when the rotating field cut the short-circuited rotor bar. Its reaction depends on torque flowing through the magnetic field. The torque produced will turn the rotor with the field. The speed of torque depends on the load needed.

METHODOLOGY

Figure 3 shows the flow chart of the pico hydro generation system. From the flow chart, it can be seen that the prototype consists of four parts; water tank, pipeline system, turbine system, and generator system.

WATER TANK SYSTEM

Figure 4 shows the complete water tank of the system. To build the water tank, 3 millimeter (mm) polycarbonate solid sheet is used and combined by using chloroform liquid. It required about 5 m x 1 m of polycarbonate solid sheet. The micro system is separated into two parts which is tank A and B. Tank A is used as the casing for the turbine system and Tank B operates as the tank for storing water that will be used for other usage. The dimension of Tank A is 600 mm length times 600 mm height times 300 mm width. While, Tank B has a dimension of 800 mm length times 250 mm height times 400 mm width.

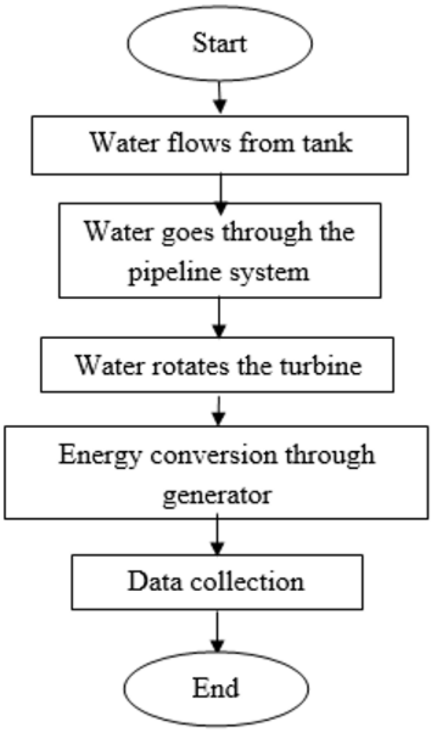


FIGURE 3. System flow chart

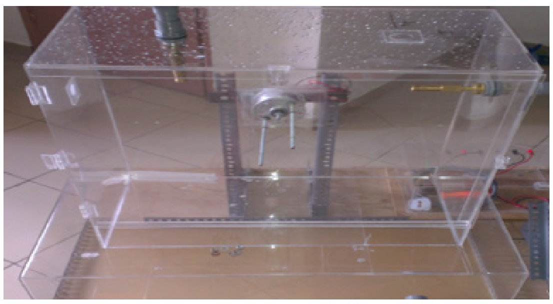


FIGURE 4. Water tank

PIPELINE SYSTEM

Figure 5 shows the pipeline system of the pico hydro generation system. The pipeline system is varied by using different combination of sizes, shapes, and positions of the turbine. In this system, the pipeline system used Polyvinyl Chloride (PVC) pipe as the main material. There are two types of size used in this pipeline system which are 20 mm and 25 mm PVC Pipe. Both combinations of pipe size are used to obtain a narrowing shape of piping system. The other combination that is decided to be used is the position of pipeline system. The pipeline system will be installed in vertical and horizontal position as shown in Figure 5. The vertical position pipeline system will operate due to the gravitational force and the horizontal position of pipeline system will operate based on the pressure inside the piping system. In this system, pin type water nozzle is used to increase the kinetic energy of the water. It is placed at the end of the piping system where the speed of the water coming out can be regulated.

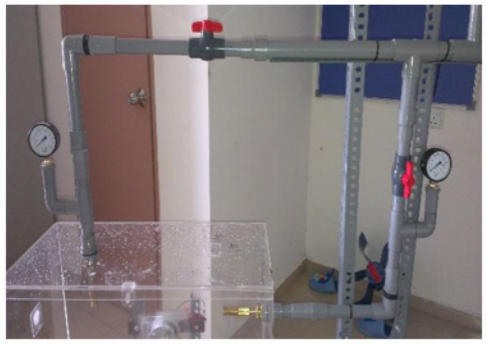
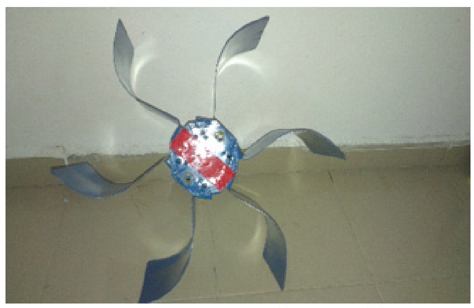


FIGURE 5. Pipeline system

TURBINE SYSTEM

Cross-flow turbine type designed for the prototype is as shown in Figure 6. For the turbine, 8 m length times 2 m width of galvanized iron sheet or GI plate is required. The GI plate is cut into six pieces in order to build six blades. It must be cut based on the desired shape of blade. The size of each plate must be 250 mm length times 180 mm width. After the GI plate is cut according to the desired shape and size, it is bent according to suitable curve where the radius of the curve is at 200 mm length.

Finally, the bottom of each cross-flow blade is folded to get 90 degree of edge by using bending machine. This process is to combine each blades in order to form a single cross-flow turbine. Each edge of blade is welded together on the circle plate. After welding process is done, two holes were made at both middle side of the turbine. The holes are used to connect the turbine to the generator by using two steel shafts.



GENERATOR SYSTEM

Figure 7 shows the Shimano dynamo hub that is used as the electrical generator to generate electricity for the prototype. It is an electrical generator that can reach maximum output at a low speed of rotation. It is very suitable to be used for this study. This is because the water pressure in this prototype is not too high. So, this machine will increase the effectiveness of this prototype in order to generate maximum electrical power with minimum water pressure.

The permanent magnet of the dynamo is stuck inside the casing of the machine. So, this part is not static and it will be operated as a rotor in order to produce magnetic field. The coils are wounded on the center shaft of dynamo and cannot be rotated because the output copper winding is stuck on the center shaft of dynamo. So, this part will be operated as a stator in this electrical generator system.

In this generating system, the positive pole of the dynamo will be connected to the positive pole of the bulb. The negative pole of the bulb is then connected to the body of the dynamo.

FIGURE 7. Shimano dynamo for generator system

TESTING PROTOTYPE

After the installation process, testing will be done by allowing water to flow through the piping system. This process is to check whether there is any leakage on the piping system. Leakage on the piping system may reduce the water pressure and will disturb the speed of turbine. Then, the stability of turbine system must be tested by hitting water on the turbine. The turbine system must be stable enough to withstand the water pressure in order to maintain the speed of rotation.

Finally, the prototype is tested to make sure it is operational. If the system is operating as intended, the light will turn on and the experiment can be done.

DATA COLLECTION

The analyzing process is conducted based on the relationship of hydro turbine speed, voltage, current, and electrical power generated due to the increment of water pressure. Pressure meter gauge is used to measure the pressure of water flowing through the piping system. Then, laser type tachometer is used to measure the rotational speed of turbine. Multi-meter is used to measure the output voltage generated through the system. Every process is repeated three times in order to get the average value of each reading.

RESULTS AND DISCUSSION

In this section, the hydro turbine speed, voltage, current, and electrical power generated will be analyzed based on three conditions of pipeline system which are condition A, B, and C. For condition A, the corresponding variables will be measured by using both water nozzles. Then, for condition B and C, the variables are measured with only either one of water nozzles operating at a time. For the study, the top water nozzle is used to measure the corresponding variables for condition B and the right-hand side of water nozzle is used to measure the corresponding variables for condition C.

DATA OBTAINED WITHOUT LOAD CONNECTED TO THE SYSTEM

COMPARISON OF ROTATIONAL SPEED DUE TO THE PRESSURE OF WATER

Figure 8 shows the relationship between rotational speed of turbine and the pressure of water. The blue, red, and green color of graph indicates the condition of A, B, and C, respectively. Based on the graph shown, each condition has different value of minimum and maximum speed. The relationship of all graphs is directly proportional to the water pressure. By comparing each graph, the best condition for this hydro generation system is condition A. This is because this condition is able to generate high rotational speed of cross-flow turbine at low water pressure. This condition only needs 1.4 Bar of water pressure to produce the maximum speed of 783.37 RPM. But, condition B and C must achieve water pressure of 2.1 Bar and 2.2 Bar respectively in order to get the maximum rotational speed of the turbine.

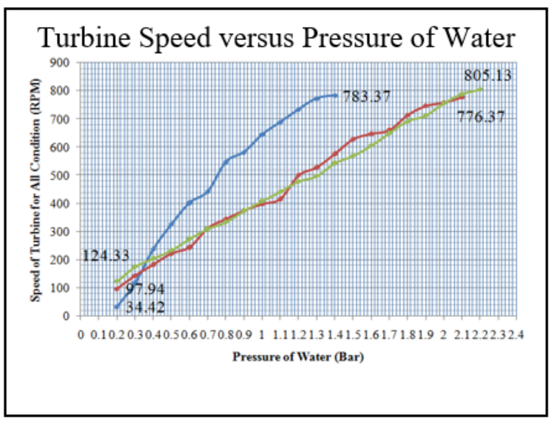


FIGURE 8. Speed of Turbine Vs Pressure of Water

COMPARISON OF POWER GENERATED DUE TO THE PRESSURE OF WATER

Based on Figure 9, the relationship between output powers generated due to the increment of water pressure is directly proportional. Each graph shows that the output power increases with the increment of water pressure. Based on the graph, the highest power generated is at condition B. But, at this condition, the maximum power generated is only achieved when the highest pressure is applied to the turbine. At 1.4 Bar, the power generated by condition B is only 96.38 Watt. This is very different to condition A where it can generate 198.19 Watt of power at 1.4 Bar of water pressure.

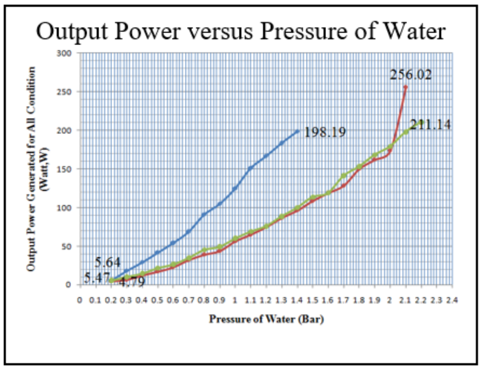


FIGURE 9. Output power vs pressure of water

COMPARISON OF VOLTAGE GENERATED DUE TO THE PRESSURE OF WATER

Figure 10 shows the comparison of three voltages due to the increment of water pressure. The blue, red, and green color of graph indicates the condition A, B, and C, respectively. The corresponding variable of voltage generated is directly proportional to the increment of water pressure. Based on the graph, the best combination is condition A because it can generate higher output voltage at only 1.4 Bar of water pressure. At this rate of water pressure, the voltage generated reached until 22.7 V. This is very different to the condition of B and C where both conditions can only achieve 15.83 V and 16.13 V respectively at 1.4 Bar.

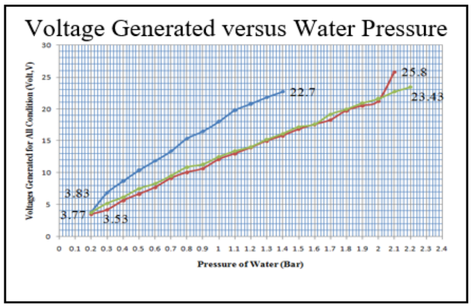


FIGURE 10. Voltage generated vs pressure of water

COMPARISON OF OUTPUT CURRENT DUE TO THE PRESSURE OF WATER

Figure 11 shows a graph comparing the relationship between the output current with the change of water pressure. In this experiment, the output current generated is directly proportional to the pressure of water. The blue, red, and green color of graph indicates the condition A, B, and C respectively. Based on the maximum value stated on the graph, some analysis can be made. The best combination is condition A because it can generate a higher output current at a lower pressure of water. It only needs 1.4 Bar in order to generate 8.73 Amp of output current. While, for condition B and C, the output current at 1.4 Bar of water pressure is only 6.09 Amp and 6.20 Amp, respectively.

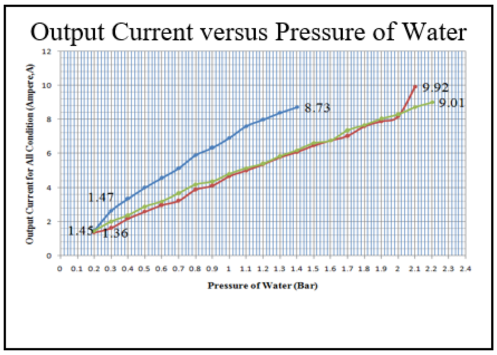


FIGURE 11. Output current vs pressure of water

DATA OBTAINED WITH LOAD CONNECTED TO THE SYSTEM

COMPARISON OF ROTATIONAL SPEED DUE TO THE PRESSURE OF WATER

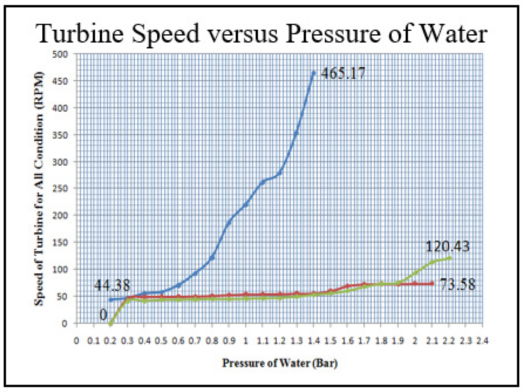


FIGURE 12. Speed of turbine vs pressure of water

Figure 12 shows the relationship between rotational speed of turbine and water pressure. In this experiment, the increment of turbine speed is very slow at condition B and C which are indicated by red and green lines, respectively.

Both conditions show that it is difficult to turn the turbine at minimum pressure of 0.2 Bar. From 0.4 Bar until 1.5 Bar, the speed of turbine at both conditions is nearly constant. The maximum speed only can be achieved at water pressure ranging between 1.6 Bar to 2.2 Bar. From this experiment, only the combination of piping system at condition A has a potential to turn the turbine at minimum water pressure. At this condition, the maximum speed is obtained at 1.4 Bar with the speed of 465.17 RPM. This is the best condition compared to condition B and C.

COMPARISON OF POWER GENERATED DUE TO THE PRESSURE OF WATER

Figure 13 shows the relationship between output power and the water pressure. The increment of output power is not constant due to the water pressure. This is because the speeds of turbine increase very slowly due to the load of the system. The highest output power achieved by condition C at 2.2 Bar of water pressure is 3.57 Watt. But, this condition is not good enough because the power generated at 1.4 Bar is only 0.78 Watt. This is very different if compared to condition A where the power generated at 1.4 Bar is 2.98 Watt. Condition A is the best combination compared to others.

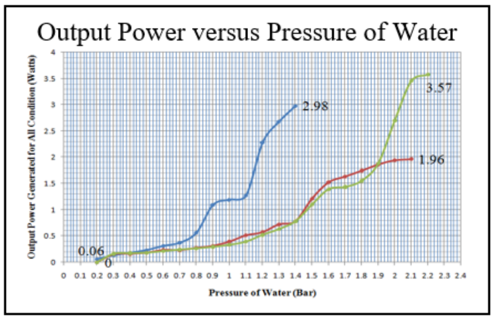


FIGURE 13. Output power vs pressure of water

COMPARISON OF VOLTAGE GENERATED DUE TO THE PRESSURE OF WATER

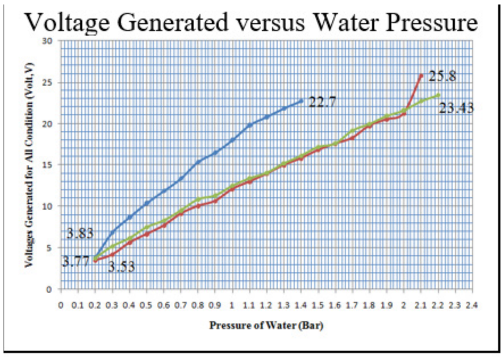


FIGURE 14. Voltage generated vs pressure of water

Figure 14 shows the responding value of output voltage due to the pressure of water. In this experiment, the relationship of voltage is directly proportional to the increment of water pressure. The increment of voltage at condition B and C is nearly the same. Both conditions B and C can only reach the maximum voltage at 2.1 Bar and 2.2 Bar respectively. This situation is very different for condition A where the highest voltage that can be generated is at 1.4 Bar. This condition requires a low kinetic energy in order to achieve the maximum voltage of 22.7 V. This is the best condition compared to condition B and C.

COMPARISON OF OUTPUT CURRENT DUE TO THE PRESSURE OF WATER

Figure 15 described the relationship between output current and the pressure of water. This experiment proved that the relationship of output current is directly proportional to the increment of water pressure. The graph shows that the best combination is condition A. This condition is able to generate maximum output current at low water pressure with the reading of 8.73 Amp, while condition B and C can only achieve the maximum output current at 2.1 Bar and 2.2 Bar respectively.

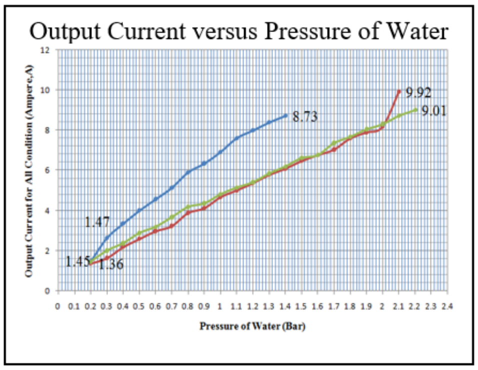


FIGURE 15. Output current vs pressure of water

CONCLUSION

Based on the results obtained, the study of the pico hydro generation system using the prototype built was successfull. The bulb that is connected through the hydroelectric system lights up when the system is running and becomes brighter when the cross-flow turbine is moving faster. The existence of load also gives an effect to the rotation speed of turbine. The load will slow down the rotational speed. Therefore, the voltage and current will drop due to the existence of load. More energy is needed if the load is increased in order to have an effective rotation. Based on the analysis, the turbine rotational speed, power, voltage, and current generated is directly proportional to the increment of water pressure. The highest power generated from the system is recorded at 198 W when no load is connected and 2.98 W with load connected.

DECLARATION OF COMPETING INTEREST

None

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