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Development on Micro Hydro Power Generator Design Using Rainwater

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Abstract: Earth's resources such as fossil fuels, coal and natural gas are used to generate electricity. As times goes by, those resources become limited. As an alternative way, renewable energy is used to generate electricity. Water or hydro energy is one of the clean and renewable energy which can be used repeatedly. The water can be converted into electricity by using water energy conversion system. Where the conversion process uses water to drive turbine which produced mechanical power thus, generate electrical energy from a generator. Since the renewable energy consumption is constantly improving, thus the electrical cost can be reduced. This is because; the price of local electrical supply is expected to soar time to time. Furthermore, the water energy is the clean energy. It has low carbon emissions, therefore the water energy is considered as green and environment friendly. However, the output will be varies based on the heaviness of the rain since our country, Malaysia has two seasons; dry and raining season. Micro hydropower generator can generate less than 100kW of power. The purpose of this project is the development of micro hydropower generator using rainwater for domestic usage. Basically, rainwater is used as a prime mover of water energy. Firstly, the rainwater will be stored in a tank before flowing into the turbine. Then, the turbine will rotate and the electricity will be generated. The recycle water from the turbine will be flowing back into the tank. So, the water could be reused. The AC voltage and current generated by the generator is converted to DC to suits the loads.

Keywords: micro hydropower generator, prime mover, turbine.

1.0 INTRODUCTION

Water or hydro energy is one of the clean and renewable energy which can be used repeatedly without emitting a large amount of greenhouse gas (GHG). In contrast, other renewable sources such as solar power which is generated via photovoltaic panels emits four times more GHGs, and a coal fired power plant produced 100 times more GHG emissions than a hydropower plant. However, the output will be varies based on the heaviness of the rain since our country. Besides, the hydropower is important resource to generate electricity especially in rural country side where there is no grid connectivity [1]. The water can be converted into electricity by using water energy conversion system. The conversion process uses water to drive turbine which produced mechanical power thus, produced electrical energy by the generator.

Theoretically, hydro power is power derived from the energy of falling water or fast running water, which may be harnessed for useful purposes. The two critical parameters involves in generating the hydroelectricity[2] are flowrate and head. Flowrate is the amount of water that can be passed through the turbine meanwhile head is the height difference between where the water enters and leaves the system.

Hydropower installation can be classified according to size of power output i.e. small and large type of hydropower[3]. Small size hydropower can be subdivided into mini, micro and pico size of power output. Generally, the small size systems can be low-wattage while generating enough energy to make a big dent in a typical domestic's energy usage and in off-grid systems even reduced the usage battery and genset.

Rainwater is used as a main source in this project to generate the electricity. Based on the article "Rainwater is used to Generate Electricity by Pluvia System in Mexico City", the concept of the Pluvia System is similar with this project. The Pluvia System is developed by Omar Enrique Leyva Coca, Romel Brown and Gustavo Rivero Velasquez. In a nutshell, the stream of rainwater runoff from houses is used to spin a micro turbine in a cylindrical

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housing. Electricity generated by that turbine is used to charge 12 Volt batteries which can in turn be used to power LED lamps or other small household appliances. Once the water flowed into the micro turbine, it proceeds to pass through a charcoal filter (remove smells, flavours and colours) and into a storage tank [4].

Due to the importance in generating electricity from free energy [5], therefore, this project focuses on developing the effective design of the micro hydropower generator by rainwater for domestic usage. Since the usage of renewable energy consumption is constantly improving, thus the electrical cost can be reduced. This project uses rainwater as a prime mover of water energy where the rainwater is stored in a reservoir (tank), before flowing into the turbine. The turbine rotates and the electricity is generated. Second reservoir is prepared to get a continuous and unlimited of rainwater source. The AC voltage and current are produced and the output converted into DC by rectifier as illustrated in Figure 1.

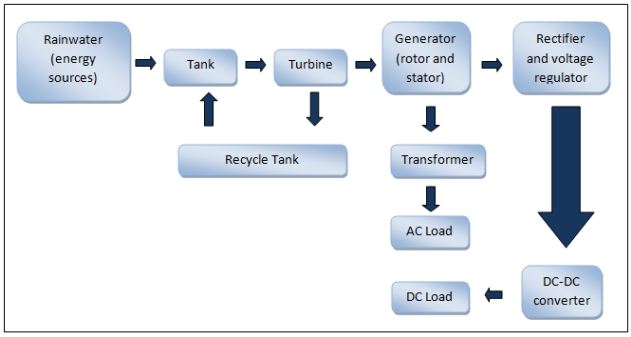

Fig.1. System block diagram

2.0 MATERIALS AND METHODS

The micro hydropower generator system is designed to suit the rainwater drainage system. The process of designing the micro hydropower generator has four stages as follows.

a) Turbine blade design

There are various type of turbine blade designs and the system employed the Pelton type for the turbine [2,3]. The turbine is designed with eight blades made from PVC pipes with the size of 6 cm length and 1.5 cm tip of the blades. The vertical part of the "L" shaped of PVC pipes fittings are removed and then cut into half equally. These fittings are attached to a plate using screws and nuts as shown in Figure 2.

Fig.2. Turbine design

b) Generator design

The purpose of the generator is to convert mechanical energy into electrical energy. The generator is designed to produce alternating current (AC) signal which voltage and current output in AC. This generator based on electromagnetism theory and energy conversation according to principle of induced e.m.f. The construction of the generator consist rotor and stator parts which the generator having permanent magnet with small-scale size to produce the electromagtism [6, 7].

Rotor is the rotating part of generator that is attached to the water turbine with 8 poles of magnet with size of 2 cm width and length each. These magnets produced magnetic field to generate the electrical signal, arranged by opposite pole and located side by side. With the arrangement of N-S-N-S-N-S-N-S, these magnets affected the electromagnetism process for one full complete cycle of 360 degree in producing the AC output.

Furthermore, stator is the stationary part of generator and is designed in this project for type SWG 23 with 250N turns of copper wire. The stator are arranged in anti-clockwise and clockwise respectively in order to get a single phase with negative and positive output. When the turbine is rotated, the stator and rotor are rotated and should be closest without touching each other so that the coils cut the magnetic fields lines in maximum range.

Fig. 3. Generator side view (left) and Rotor design (right)

c) Hardware setup

The micro hydropower generator system is set up as illustrated in Figure 1. The system is designed to suits both seasons. Therefore, the system can be used for direct roof drainage and from the water tank. First tank is used to

supply and force the turbine to rotate and the second tank is used to recycle the water and pumped the water to the first tank. The water level is detected [8] and measured using Hydor Smart Level Control sensor to avoid water overflow in tank. The transformer is used to step up the output to suits the AC output [9]. In order to attach with any 12V DC load [10], a rectifier and DC chopper [11] is needed.

d) Data collection

Since Malaysia has dry and rainy seasons, this system must work efficiently during both seasons. This experiment setup has two conditions to satisfy the actual application. The two conditions of the water drainage are as follows:

i. Use rainwater storage (from tank)
ii. Use direct roof drainage

The amount of voltage and current are measured using a digital multimeter while the rotation speed of turbine is measured using tachometer. For voltage and current of AC signal, the digital multimeter is connected to the turbine. Next, a tachometer is placed near the rotating turbine to obtain the rotation speed. The readings are tabulated and analyzed.

3.0 RESULTS

i. Using rainwater storage (direct from tank)

Table 1 shows the output obtained based on the first condition set up. The reading was taken at every 5 minutes. The tabulated data are presents in graphs as in Figure 4 and Figure 5 for better comprehend. Note that, this results are AC output measured directly from the generator. The observation shows the highest speed of turbine rotation is 203rpm that generates 0.87V and 0.062mA outputs.

Table 1. Result for speed of rotation, voltage and current using rainwater storage.

Time sequence (min)	Speed of rotation (rpm)	Voltage (V)	Current (mA)
1	203.1	0.87	0.062
2	200.3	0.79	0.057
3	198.4	0.76	0.043
4	195.7	0.69	0.038
5	192.1	0.64	0.032
6	196.5	0.71	0.039
7	197.0	0.73	0.041
8	196.6	0.71	0.039
9	196.2	0.70	0.038
10	195.8	0.69	0.038

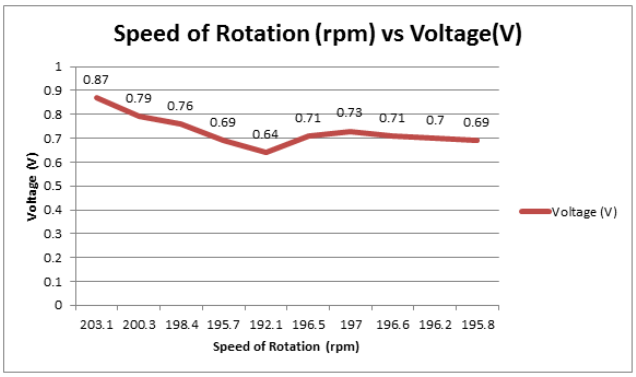

Fig. 4. Graph turbine speed versus AC voltage output

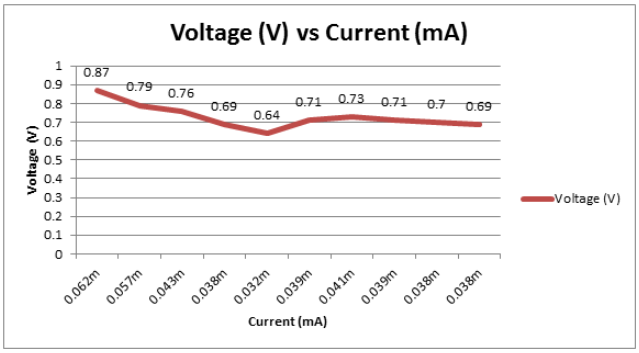

Fig. 5. Graph AC voltage output vs current

ii. Using direct roof drainage

Table 2 shows the data collected for the second set up and measured at the generator. The data are plotted as in Figure 6 and Figure 7. The observation shows the highest of speed of rotation is at 1045rpm generates outputs 7.6V and 196mA. Note that, the reading was taken for 1 hour and measurement was taken at 6 minutes interval. The rain stated to be heavier at 30 minutes.

Table 2. Result for speed of rotation, voltage and current based on direct roof drainage.

Time sequence (min)	Speed of rotation (rpm)	Voltage (V)	Current (mA)
6	197	1.0	126
12	250	1.9	141
18	375	2.1	143
24	573	3.0	155
30	601	3.6	163
36	683	4.7	170
42	750	5.8	179
48	856	6.1	180
54	984	6.5	183
60	1045	7.6	196

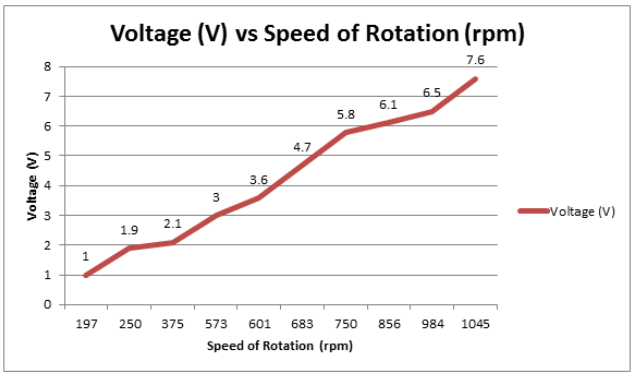

Fig. 6. Graph turbine speed versus AC voltage output

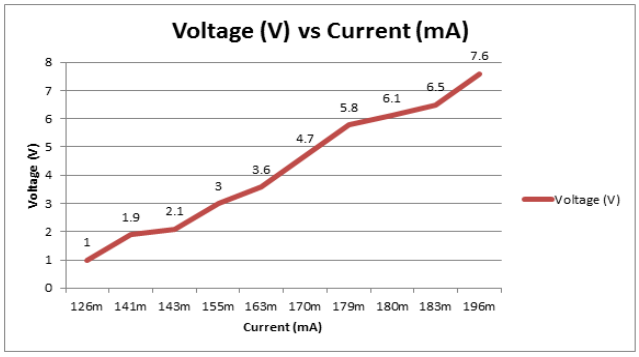

Fig. 7. Graph AC voltage output vs current

4.0 DISCUSSION

By analyzing the results obtained from both conditions with different experiment set ups, it can be said that for the first condition (rainwater storage) produces almost consistent output. However, at the beginning of the data collection, the speed of the turbine is at the highest. This is due to the Bernoulli effects where the pressure is lower and the force of the water is high at the bottom opening of the tank [12]. For the second set up, the generator is placed at a distance from the roof drainage to create free fall effect of the rainwater to the generator. Within that 1 hour of data collection process, at 30 minutes the rain started to falls heavily. Therefore, slight increment in turbine speed. The faster the turbine rotates, higher output will be generated. The speeds is increases within the last 30 minutes. The highest speed recorded is at 60 minutes with the speed of the turbine is 1045rpm that generates 7.6V with 196mA.

5.0 CONCLUSION

The designed micro hydropower generator to suits the drainage system works efficiently for both seasons; dry and rainy seasons. The usage of reservoir or tank is used for rainwater catchment. In the case for dry season, the rainwater will be recycle and kept in the second tank. This will make sure the system can be fully operated during dry season. For rainy season, the generator can be operated and generates more electricity on heavy rain. The speed of the turbine will determine the amount of the output generated from the system. Higher the speed, greater the output.

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