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Development of Micro Hydro Generator using Rainwater for Domestic Usage

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Abstract: The main sources of energy used for the generation of electrical energy are water, fuels, nuclear energy and other related source that have been widely used all over the world. For water energy, hydro generator is used to convert kinetic energy from the water flow into electricity. In hydroelectric power plants, each generator is capable in generating from few kW to thousands of MW. However for domestic usage, a micro hydro generator can be used if the generating capacity is less than 100kW. Micro hydro can provide alternative renewable energy sources especially in areas like small rivers, stream flowing or building. The choice of energy source depends on several factors, including availability, economic and energy and power requirements. Micro hydro power is cost-effective than any other form of renewable power. Micro hydro used in this project has output less than 500W. This project involves two parts of the generator; mechanical and electrical. The mechanical part involves the process of rainwater intake. This is the part where the beginning of the power generation of the system. It involves the design of the casing, turbine and a set of rotor and stator. Meanwhile, the electrical part is more on the power conversion that employed components such as rectifier, DC load, DC-DC converter, charging circuit and battery for storage purposes. In the end of the project, the micro hydro generator functions as expected and able to produce output power more than 2.5 Watt with 8V DC voltage and 250mA DC current at the highest speed of rotation i.e.1000rpm. The response varies depending on the amount of rainwater and its flow rate that hits the turbine.

Keywords: Micro hydro generator, stator, rectifier, DC-DC converter.

1.0 INTRODUCTION

The energy conservation is a law of physics which state that energy cannot be created or destroyed. The kinetic energy stored in the moving rainwater changes multiple times as it falls through the hose, spins the turbine, rotate the generator and light up the load. The generator produces electricity by transforming mechanical energy to electrical energy. This transformation occurs due to special relationship between electricity and magnetism that called electromagnetism. The Central Electricity Authority (CEA) and the Ministry of New and Renewable Energy (MNRE) have classified SHPs depending on capacity range and available head. The classifications are regarding range of power produce which known as; micro when its unit size 0 up to 100kW, mini with unit size 101-1000kW and small will be categorized in 1-25MW [1].

Micro hydro generator promotes the use of green energy from rainwater. Although it generates small output power and is suitable for domestic usage, but with proper design of the generator, the output power generation can be improved. Therefore, this project focuses on the concept of micro hydro generator in terms of the design and its functionality. The key concept operation principle of a generator adopts the concept of electromagnetic induction that defines by the Faraday's Law and the equation as follows [2]:

$$E_{emf} = -N\frac{d\Phi}{dt} \qquad (1)$$

where N is the number of turn of a coil and $d\varphi/dt$ is the rate of change of the number of magnetic flux lines passing through the surface, A enclosed by the coil as stated in the equation below [3]:

$$\varphi = B \times A \qquad (2)$$

where φ is proportional to the effective area, A of the loop of a coil and B is the magnetic flux density.

Meanwhile, in designing the generator, one of the important factors the number of turns of the copper coils

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that gives effect on the output produced. The output is known as Magnetomotive Force (Fm) which is produced in the existence of a magnetic flux in the magnetic circuit as shown in the equation below [2]:

$$F_m = N \times I \qquad (3)$$

In addition, the Faraday's law is applied in the concept of a generator; to convert the mechanical energy into electrical energy. The conductors that forming electric circuit is made to move through the magnetic field and this will create the source of electromagnetic force (e.m.f) as shown in equation below [2]:

$$E = Blv \sin \theta \qquad (4)$$

where θ is the direction of conductor movement towards magnetic field and *l* is the length of the inductor coil.

Figure 1 illustrates the electromagnetic force induced in the coil that is proportional to the number of turns with the rate of change of the flux with time [3]. When the magnetic flux lines produce and pass through the surface that encloses by the coil, e.m.f is induced but in oppose direction.

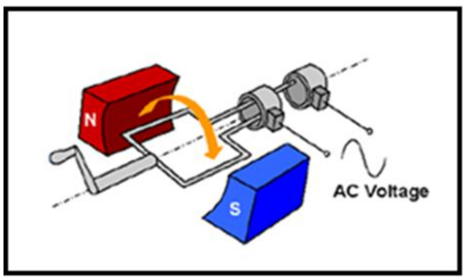

Fig. 1. Electrical generator concept [3]

2.0 METHODOLOGY

This section is divided into two main parts; the mechanical and electrical. The description begins with the main system design of the micro hydro generator. Mechanical part discusses on the hardware and the generator design. In generator design, it focuses more on the arrangement of the permanent magnets (rotor) and the number of turns of the copper coils (stator). Electrical part describes on the conversion system and the load. The final part of methodology explains on the procedure undertaken for data collection.

A. Micro Hydro Generator System Design

The overall system of a micro hydro generator for rainwater is illustrated in Figure 2. There are three main sections divided in the system; energy generation and conversion, load and storage. In the first section, the rain water intake from the roof drainage is directed to the micro hydro generator; where the rainwater hits directly to the turbine. When the turbine rotates, the kinetic energy produced is then converted into electrical energy by the generator. With the aid of the rectifier and voltage regulator as components of system conversion the AC voltages from the generator can be converted to DC voltage and the output voltage is regulated using voltage regulator. In addition, the output voltage can be step up using DC-DC converter namely DC chopper so that the voltage is match with the load and the storage system. The emergency lamp act as the load and gets the supply direct from the generator. Some of the power produced is kept in a battery. This enhances the system design which can be used during dry season.

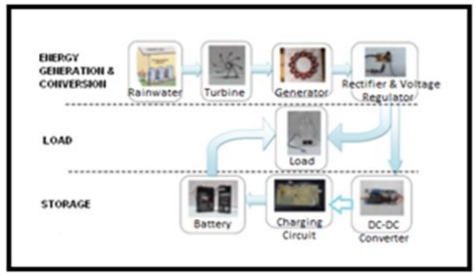

Fig. 2. Micro hydro generator system block diagram

B. Micro Hydro Generator Design (Mechanical)

In designing a micro hydro generator, proper hardware design is required for the smoothness generation process. The casing of the generator is designed as illustrated in Figure 3. Perspex is used as a casing. With a transparent material like Perspex, the movement of the turbine can be observed. On the Perspex, there were two holes made as inlet and outlet for the rainwater.

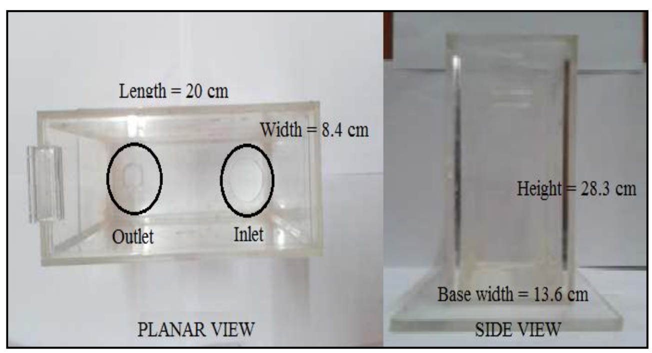

Fig. 3: Casing design of micro hydro generator

Nozzle is a head that used to increase the speed of water coming from the roof drainage. In Figure 4, two different sizes were used; 3 cm (inlet) and 0.6 cm (outlet). The pressure produced by the inlet nozzle increases the speed of the turbine rotation.

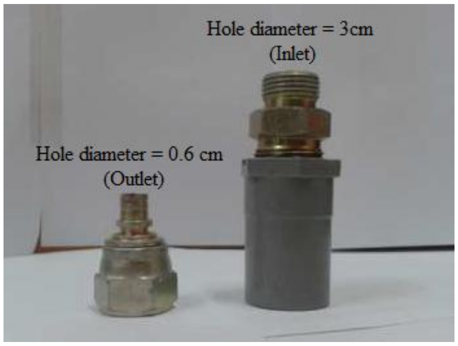

Fig. 4: Nozzles size

Turbine is one of important part in the system since the rotor of the turbine rotates and generates electricity. The turbine is designed to have 8 blades and made up of plastic material so that the turbine would be lighter and easy to rotate with low torque. The blades are attached to the pipe (shaft) with 6 cm length and 1.5 cm tip of the blades as shown in Figure 5.

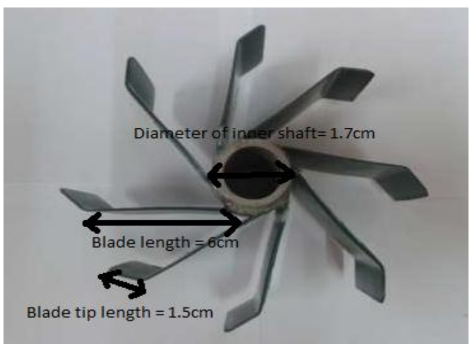

Fig. 5. Turbine size

C. Generator Design

i. Neodymium Magnet n-48 Arrangement as Rotor

A square shaped neodymium magnet N-48 is a magnet that is composed of alloys from lanthanide group element. The two lanthanide elements that is most prevalent in the magnet productions namely the Neodymium (Nd) and Samrium (Sm) [4]. This strong magnet is used with the dimension of 2 centimeters (length) by 2 centimeters (width). This magnet has 4 sets with north and south poles with 2 centimeters outer shaft diameter. The arrangement of the magnet is in opposite pole and located side by side; N-S-N-S-N-S-N-S as shown in Figure 6. This arrangement has higher magnetic field density and it also affect the elctromagnetism process of one revolution (complete cycle) of 360 degrees to produce AC output [5].

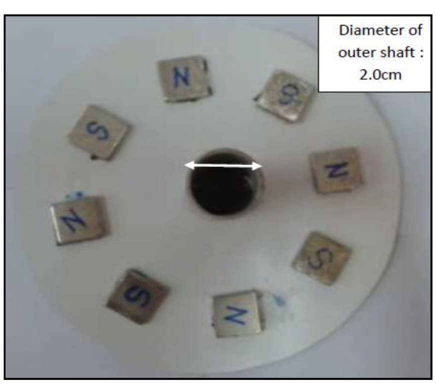

Fig. 6. Magnet arrangement

ii. Stator Design

Stator is the stationary part of the generator. It is made of a copper winding with two different sizes; SWG 23 and SWG 27 [6]. The stator is analyzed to determine the best performance in term of the output produced. The copper wires is set to have 200, 250 and 300 turns in 8 sets of copper coils. The stator is designed to be flexible so that it can be attached and detached from the main body of the generator.

iii. Rotor and Stator Construction

The construction of the rotor and stator is illustrated in Figure 7. The eight copper coils that placed on the stator are arranged in anti-clockwise and clockwise respectively. This is to assure that the output is in single phase and having the positive and the negative pole outputs (polarity). The stator is attached to the main body of the generator meanwhile the rotor is attached to the shaft of the water turbine. The separation distance between the rotor and stator is minimized without touching to each other. This is to make sure the copper coils cut the magnetic field lines in maximum range.

The resistance of the copper wires with different sizes and number of turns were measured. The speed of the rotation is measured using tachometers. The speed of the rotation is varied in 200, 500 and 900 rpm. The output voltage is measured using voltmeter. The data collection was repeated for five times to validate the data obtained.

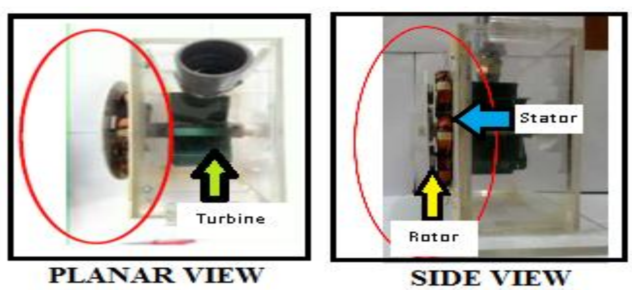

Fig. 7. Construction of generator

D. Conversion System for Micro Hydro Generator (Electrical)

In this section, electronic circuit will take part in order to rectify and regulate the output signal form generator before entering load. The first electronic part is rectifier and voltage regulator of 9V and 6V using KIT-162 DC 6V/9V Regulator Supply. The function of rectifier is to rectify the

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AC output from the generator to DC signal. Meanwhile, the voltage regulator is used to regulate voltage between 6V to 9V controlling by a switch and LED as an indicator to show either the circuit is functioning or not. The DC output from rectifier and voltage regulator will be used to light up the emergency light that only consume 2.5W of power. The minimum dc voltage required is 4V with 4.5AH of current. The brightness of the light will be depending on the supply voltage from the output voltage obtained in this project. Step up DC-DC converter is an adjustable power circuit with minimum input 3V dc signal. The output can be adjusted according to user's need until maximum voltage, 36V dc. The circuit shown in Figure 8 is used in order to invert the signal from rectifier circuit up until 12V dc to activate charging circuit. The charging circuit needs at least 12V dc as its input to operate. The charging circuit uses 12V solar panel that consists of 1.2V rated at each panel. Therefore, 12V dc input needs to activate this charging circuit in order to charge the battery. The charging current will flow through the D1 and enter the voltage regulator of IC LM 317. Resistance with 1kΩ of R4 is placed in grounding path so that it can provide 9V output voltage to the battery. Resistor R3 with 10Ω/1W will restrict the charging current and diode D2 prevents discharge of current from the battery. Transistor T1 and also zener diode ZD act as cut off switch when the battery is fully charged. In normal condition, the transistor Q1 will be in off mode and the charging current will flow to the battery. When the terminal voltage of the battery rise above 6.8V, zener diode will conduct and provide base current to transistor T1 and turn the grounding path of LM317 to stop charging. A rechargeable battery is used for energy saving purposes. The 6V and 9V battery with the same capacity 4.5AH are chosen to be charged when the main source from TNB is not being used.

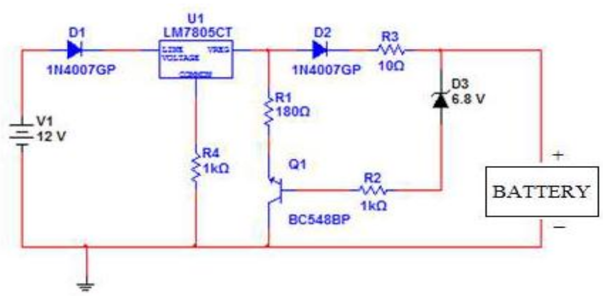

Fig.8. Charging circuit in simulation drawing

E. Experimental Setup for Data Collection

The setup for the stator performance testing is done by using tap water as a mimic to the rain water. The flow rate of water that hits the turbine is controlled based on the tachometer readings at 200, 500 and 900 rpm. At this speeds, the open source of AC at the stator side were then measured using multimeter. The open source of AC is the measurement of the output voltage between the first copper coil's input wire and the eighth copper coil's output wire. The connection in measuring the output voltage at the open source is illustrated in Figure 9. All the readings obtained from the output are recorded. The design of this generator is extended to have a rectifier circuit so that the output in AC will be converted into DC output. This conversion will make sure the generator is able to supply the DC loads such as battery charger and light. Other than rectifier circuit, this micro hydro generator is equipped with DC to DC converter namely the chopper and voltage regulator to assure the output can be varied depending on the loads.

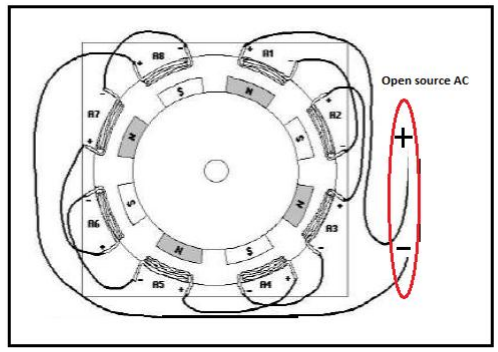

Fig. 9. Construction of stator and rotor

2.0 RESULTS AND ANALYSIS

A. Resistance of Copper Coils

Table I shows the differences on resistance value for various numbers of turns applied for eight coils. It can be said that the higher number of turns applied the higher the resistance value. The SWG 27 which has diameter of 0.4 mm has the larger resistance compared to SWG 23 with 0.6 mm.

COPPER RESISTANCE FOR SWG 23 AND SWG 27

Type of copper wire	**SWG 23**			**SWG 27**		
Copper diameter (mm)	0.64262			0.40386		
No. of turn (N)	200	250	300	200	250	300
Resistance of wire for 8 coils (Ω)	10.8	12.4	16.0	17.0	24.5	27.5

B. Effects on Rotation Speed of the Turbine

Table II to Table IV show the output voltage measured when several of rotation speed range i.e. 200, 500 and 900 rpm were applied to the rotor. The comparison was made to the different size of the copper wire size; SWG 23 and SWG 27 with number of turns of the coils applied; 200, 250 and 300 turns accordingly. The output voltage

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produced at speed 200 rpm, SWG 23 gives better output compared to the SWG 27. As the speed increases, the output voltage produced is also increases. The SWG 27 is small in diameter compared to SWG 23 but it has higher resistance. The resistance will limit the amount of current produced which proved by the Ohm's law where the larger the amount of resistance, the lower the current produced. Figure 6 illustrates the output voltage produced based on various parameters; copper size, number of turns and rotation speed. The open AC voltage is measured at the output port of copper coil (refer Fig. 4). Based on the graph obtained, the best output produced by SWG 23 with 250 turns. At the beginning of the rotation, the output voltage is a bit unstable. As it reaches 300 rpm, the output seems increases linearly and produces the highest output voltage compared to other parameter settings. When the output of the generator is connected to a rectifier and a voltage regulator, it can be said that with SWG 23 with 250 turns the light is turned on. With SWG 23 (250 turns) gives the best output compared to the others in terms of the AC output voltage and output current as shown in Table V.

TABLE II. OUTPUT VOLTAGE AT 200 RPM

Speed of rotation	**200 rpm**					
Type of copper wire	SWG 23			SWG 27		
No. of turns	200	250	300	200	250	300
No. of poles	8	8	8	8	8	8
No. of coil	1	1	1	1	1	1
Resistance value (Ω)	1.4	1.6	2.0	2.1	3.1	3.4
Open AC voltage (V)	2.0	0.75	2.4	1.0	2.0	0.9

TABLE III. OUTPUT VOLTAGE AT 500 RPM

Speed of rotation	**500 rpm**					
Type of copper wire	SWG 23			SWG 27		
No. of turns	200	250	300	200	250	300
No. of poles	8	8	8	8	8	8
No. of coil	1	1	1	1	1	1
Resistance value (Ω)	1.4	1.6	2.0	2.1	3.1	3.4
Open AC voltage (V)	4.7	4.8	4.6	2.2	4.0	1.8

TABLE IV. OUTPUT VOLTAGE AT 900 RPM

Speed of rotation	**900 rpm**					
Type of copper wire	SWG 23			SWG 27		
No. of turns	200	250	300	200	250	300
No. of poles	8	8	8	8	8	8
No. of coil	1	1	1	1	1	1
Resistance value (Ω)	1.4	1.6	2.0	2.1	3.1	3.4
Open AC voltage (V)	6.4	9.0	8.7	5.3	5.7	3.4

TABLE V. OUTPUT READING FOR SWG 23 (250 TURNS)

Rotation speed (rpm)	200	500	900
Resistance	12.4	12.4	12.4
Output AC voltage (V)	0.75	4.8	9
Output AC current (mA)	63.6	126.9	250.0
Output DC voltage (V)	0.5	4	8
Output DC current (mA)	0.04	0.17	0.25
Light Response	OFF	ON	ON

4.0 CONCLUSION

Based on this study, it can be concluded that proper coil size and the number of turns did affect the performance of a generator. Therefore, the more number of turns applied will contribute to high resistance and this decreases the amount of output voltage produced by the generator.This study can be extended to have a double stator and a proper tank to recycle the rainwater so that the generator will have enough supply to assure the turbine rotates continuously and produce enough supply to the loads.

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