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Development of Micro Hydro Power Plant Prototype as A Field Laboratory for Educational and Research Purposes

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***Abstract*—The need for cheaper electricity generation rises as the price of fossil fuels is increasingly nowadays. Hydropower plant is one of the most efficient and environmentally friendly alternative power plant sources. In this research works, a prototype of small-scale hydro power plant known as micro hydro power plant (MHPP) was developed for educational and research purpose. The motivation of this work is based on there is no field laboratory could be used for students to study the concept and actively involved in electricity generation at *Universiti Teknologi Malaysia* (UTM) Johor Bahru campus, Malaysia. This work hopefully become the catalyst for further research regarding renewable energy source, particularly in MHPP research. The research flow for this work begins with feasibility activities to determine some potential sites for development of MHPP at UTM Johor Campus. There are 7 (seven) potential sites based on site visits and data analysis. From the data analysis, the most suitable site chosen for MPPP prototype development. The prototype was built based on the improved design. The results show that the constructed prototype is capable for generating electricity. This prototype can be used as a field laboratory and for educational and research purpose.**

Keywords—micro hydro power plant, water flow, field laboratory, output voltage, output power.

I. Introduction

Micro hydro power plant as one of renewable energy source is a small-scale power plant that uses hydropower as its driving force such as irrigation canals, small rivers or natural waterfalls by utilizing the head and the amount of water discharge. Technically, micro-hydro power plant has three main components, namely water (as an energy source), turbine and generator. This power plant gets energy from the flow of water that has a certain height difference. Basically, it utilizes the potential energy of falling water (head). The higher the water drop, the greater the potential energy of the water that can be converted into electrical energy. In addition to geographical factors (river layout), the height of falling water can also be obtained by stemming the flow of water so that the water level becomes high. It is a system of converting energy from the form of height and flow (potential energy) into the form of mechanical energy and electrical energy. The incoming power (Pin) is the sum of the generated power (Pout) plus the energy loss factor (Ploss) in the form of sound or heat. The power produced is the product of the input power multiplied by the conversion efficiency.

The difference between a normal hydroelectric power plants and a micro-hydro one, especially in the amount of electricity produced, hydropower under the size of 200 kW is classified as micro-hydro. The relatively small amount of energy produced by micro-hydro compared to large-scale hydropower, has implications for the relatively simple equipment and small area required for micro-hydro installation and operation. This is one of the advantages of micro hydro, which does not cause environmental damage. Thus, the micro-hydropower system is suitable for reaching the availability of electrical energy networks in remote and rural areas that are not able to be reached by the power electricity company like TNB in Malaysia. Moreover, it is necessary for engineering student, particularly electrical engineering student to know the concept and actively involved in development of micro-hydro power plant.

According to TNB, source of hydropower electricity in Malaysia is about 18,500 MW and this represents about 20% of total power plant in Malaysia [1-2]. For micro-hydro power plant, Malaysia has also great potential due to the hilly topography of many places in this country [3].

Moreover, it is necessary for engineering student, particularly electrical engineering student to know the concept and actively involved in development of micro-hydro power plant. The objective of this study is mainly to perform a feasibility study on micro hydro power plant (MHPP) potential in UTM Johor Bahru Campus as a site laboratory for research and educational purposes. This work including design of the MHPP prototype based on the data gathered and calculation and construction the prototype of MHPP at the most potential site in UTM Johor Bahru Campus.

II. METHODOLOGY

From feasibility study which perfome at UTM Johor Bahru Campus, it came up with 7 (seven) potential sites which possible to be taken as MHPP site. These sites have constant water flow and good water head values. The potential sites are: (A) Lake UTM, (B) Islamic school, (C) FKE new block, (D) Nearby FKE P19, (E) Nearby FKA building, (F) Quarantine center, (G) Nearby UTM health clinic. The pictures of the all locations are shown in Fig. 1.

(a) UTM Lake

(b) UTM Islamic School

(c) FKE Block P19a

(d) FKE Block P19

(e) FKA Block G02

(f) Quarantine Center

(g) UTM Health Center

Fig.1. Potential locations for micro hydro power plant (MHPP) at UTM Johor Bahru Campus

Current meter (Swoffer Model 3000) is used to measure the flow rate of water in meter cube per second. In order to get the required flow rate of meter cube per second, the area of the measured water is needed. By multiplying the calculated area and the measured velocity, the flow rate of water in meter cub per second can be obtained. For the measurement of head of water, precise level meter (Pentax AP-201) is being used. Fig.2 shows the photograph of the current meter and precise level which are used in this research work.

The most important formula for this research work is the output power formula as stated in equation (1) [4-6].

$$P = \frac{\rho g Q H \eta_0}{1000} \qquad (1)$$

Where,

P = Output power in kW
ρ = Density of water (1000 kg/ m3)
g = Acceleration of gravity (9.81 m/ s2)
Q = Water flow rate (m3/ s)
H = Head of water (m)
η_0 = Overall efficiency (50%)

(a) (b)

Fig. 2. Equipment for feasibility study, (a) water current meter (Swoffer Model 3000) and (b) precise level meter (Pentax AP-201) [7].

The main construction of micro hydro power plant prototype is contained of water wheel, gear, water channel/penstock, alternator, and supporting material for water wheel. We utilized motorcycle wheel and used engine oil bottle as a water wheel and its blades as shown in Fig. 3.

Fig. 3. Prototype of water wheel

III. Result and Discussion

Table 1 shows the velocity of water measured using current meter at seven potential locations for MHPP construction. The velocity measured in meter per second is converted to meter cube per second by multiplying the average velocity values with the cross-sectional area of the measured water. The results are shown in Table 2.

Once all the needed data are available, the calculation of output power can be calculated using equation (1). Fig. 4 shows the graph of calculated output power for all potential locations for MHPP construction. As can be seen clearly from the figure, location (G) has the highest calculate output power so that it is chosen as the MHPP construction site. Fig. 5 shows the photograph of MHPP prototype construction at the chosen site (G).

TABLE I. The Velocity of Water Measured Using Current Meter (Swoffer Model 3000)

Site	Velocity 1 (m/s)	Velocity 2 (m/s)	Velocity 3 (m/s)	Velocity 4 (m/s)	Average Velocity (m/s)
A	0.2350	0.2470	0.2390	0.2350	**0.2390**
B	0.6130	0.6050	0.6010	0.5890	**0.6020**
C	0.7100	0.7010	0.6670	0.7500	**0.7070**
D	0.4500	0.5200	0.4300	0.5840	**0.4960**
E	0.2200	0.1800	0.2300	0.2000	**0.2075**
F	3.2760	3.2210	3.3420	3.2770	**3.2790**
G	4.9800	4.9700	4.9700	4.9800	**4.9750**

TABLE II. The Calculation of Water Flow Rater for All Locations

Site	Area (m^2)	Velocity (m/s)	Flow Rate (m^3/s)
A	0.0300	0.2390	**0.0072**
B	0.0500	0.6020	**0.0301**
C	0.1560	0.7070	**0.1103**
D	0.0400	0.4960	**0.0198**
E	0.0420	0.2080	**0.0087**
F	0.0126	3.2790	**0.0413**
G	0.0317	3.5750	**0.1133**

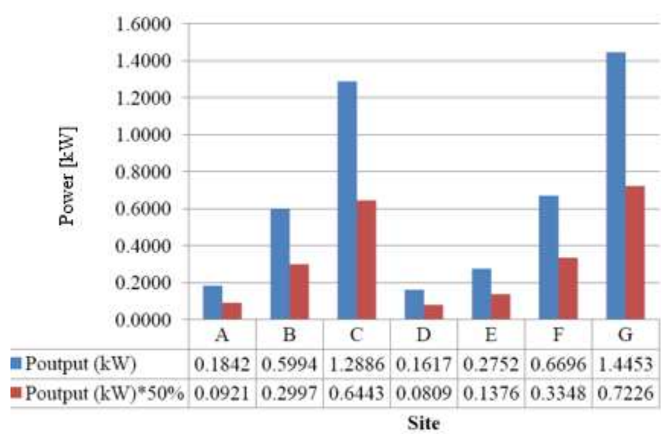

Fig. 4. Result of calculated output power for all locations

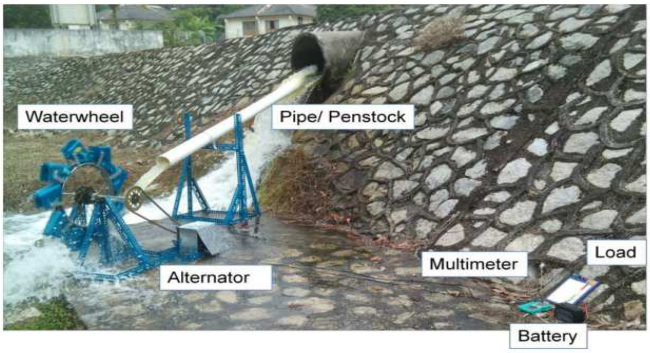

Fig. 5. Photograph of MHPP prototype construction at the chosen site (G).

The results of measurement of output voltage, current, and electrical power for trial 1 to 4 are as shown in Fig. 6. As can be seen from the graph, the values of such quantities increased as the trial increased. This increased output quantities due to the increased of current when the trial number is increased from trial 1 to 4.

Figure 7 shows the graph of difference values of trial results at the real MHPP and the design results. The lowest trial result is 1.8132 watt which is from trial 1. The highest trial result is from trial 4 which is 5.4750 watt. As can be seen clearly in the figure, the highest average output from trial 4 is only 10.67% compared to design results 1 and 22.43% compared to design results 2. The lowest average output which is from trial 1 with the value of 1.8632 watt is only 3.81% from design results 1's value and 7.97% from design results 2's value. According to observation during trials, it is found several factors which influenced the output power at the real MHPP, namely low rpm value of water wheel, low flow rate, and low head value of the penstock/pipe, respectively.

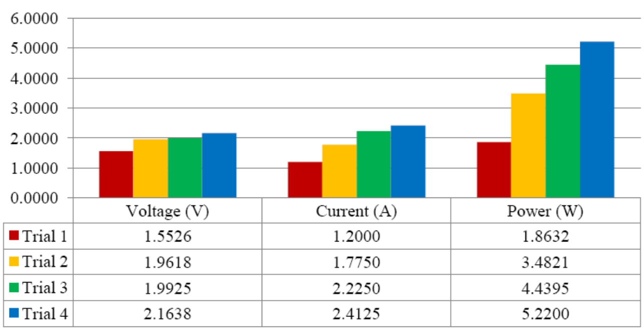

Fig. 6. Value of output voltage, current, and power for trial number at site G

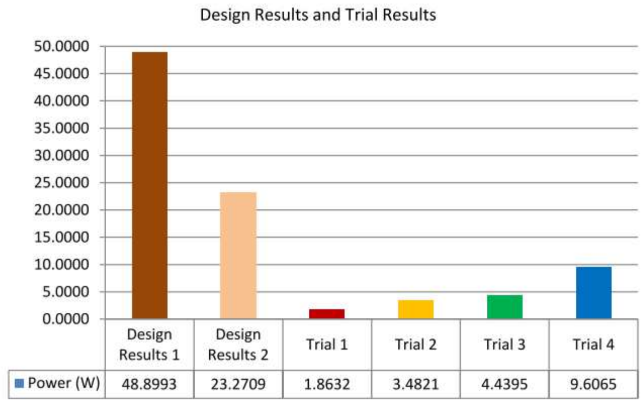

Fig. 7. Output power obtained from design result and trial result at the MHPP prototype

IV. CONCLUSION

In this research work, a prototype of a micro hydro power plant (MHPP) has been successfully developed. This work has identified seven potential locations MHPP site in UTM as a site laboratory for research purpose. During the calculations of theoretical results that are based on the data gathered at the locations, the highest output power is achieved at site G (near UTM health clinic). This prototype system could be utilized as site laboratory for educational and research purposes.

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