Development of Residential Energy Harvesting System with Arduino Application

Mohd Syahrin Amri[1], Mohamad Ikhwan Shah[1], A.F. Kadmin[1] and Z. Zakaria[2]
[1]*Fakulti Teknologi Kejuruteraan Elektrik dan Elektronik, Universiti Teknikal Malaysia Melaka,*
[2]*Fakulti Kejuruteraan Elektronik dan Kejuruteraan Komputer, Universiti Teknikal Malaysia Melaka,*
syahrin@utem.edu.my

***Abstract*— The common electricity source is currently being generated through solar panel, wind turbine and hydroelectric. However, these methods require high cost and large space for the system operation. This paper proposed a Pico hydro free charging system from high pressure water of the home piping system stored to power bank for home lighting application. The usage of small-scale turbine in the system generated electricity to continuous charging the power bank. The power bank then acted as a free power source used to light up a 5V LED bulb as a free lighting source. The additional usage of Arduino helped to provide the information display on the generated current, voltage and the water flow rate. The piping size and length were evaluated and it was found that they significantly affected the voltage performance with the help of Arduino application for monitoring purpose. The uniqueness of this project is that it can be operated with a minimum water pressure of 15 Psi to generate renewable energy storage from incoming housing piping system.**

***Index Terms*— Arduino; Housing Piping; Pico Hydro; Renewal Energy**.

I. INTRODUCTION

The existing housing water system in Malaysia is using water-piping system to supply water to the water tank allocated under the roof. High water pressure becomes an important requirement to ensure the water reaches the water tank allocated at a higher area. With the high pressure applied towards the piping system, it is an opportunity to generate free electricity by using pico-hydro water turbine. To develop the system, the voltage and current performance are monitored by evaluating two types of piping diameter size, and this low investment with simple piping system suits the pico hydro application [1]. The free generated electricity is used to charge the 4000 mAh power bank as the power source. The concept of turbine in the system is basically the same with the others: It converts the flow of water in the piping system into mechanical rotating energy, which then converts it to electrical energy that is considered as usable energy[2].

For years, the common ways to generate free electricity are from the sun, wind, ocean or river, and this method has shown an encouraging trend. Another way to get free electricity is from our residential area [3]. The objectives of the project are to generate free electricity from residential system and to evaluate piping criteria that contribute to the highest voltage value for charging purpose. Water is one of the best source to produce free electricity[4] and this idea had been implemented for this project. The pico hydro turbine will be used to generate 12V, in which a circuitry will be applied to step down the voltage to 5V for charging the power bank. The power bank will be used to light up the 5V bulb when it is required. The idea on how to generate free electricity for home lightning can be referred to Figure 1.

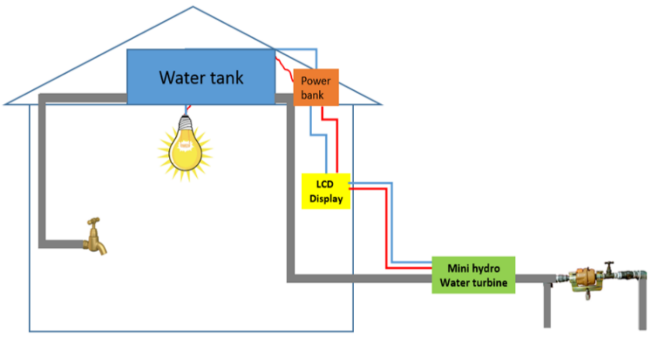

Figure 1: Idea of the piping system

Turbines output can be influenced by several factors such as ranges of head together with flow rate. Power generated below 5kW is defined under Pico range [5]. Head and flow are the main important components of water-power to produce electricity. The head is defined as the pressure, measured in Psi while, the flow rate is measured in Liter / hour. The voltage and current are monitored based on the programming using the Arduino Uno application. Arduino Uno reads the information from the input devices [6] such as sensor and displays it through Liquid Crystal Display (LCD) for monitoring purpose. The data collection is conducted according to the real time of voltage and current value generated from the water flow rate and the water pressure itself.

The Pico hydropower system has its own advantages, which are small scale, environmental friendly and cheaper compared to solar Photovoltaic, which has been increasing competitively [7]. The designed system was compared with the conventional solar and wind turbine system; it was found that the system is more stable that the former system in terms of power generation due to the consistency of the high pressure from the incoming water. With respect to the conventional method, the solar depends on the amount of sunlight affected by weather, especially in raining condition, while the wind turbine needs continuous strong wind blowing. H.Zainuddin [8] had developed the same pico-hydro system at the housing area; however, the charging was based 9.6V, 700 mAh Ni-Cad rechargeable battery. In order to fill the gap on an improvement, a system by charging the power bank for the energy storage has been developed. The power bank is used to light up the 5V LED bulb throughout the USB slot, in which currently there is a lot of electrical appliances using USB feature based on low voltage application.

II. Methodology

The scope of assessment had been set based on specific criteria during the assessment. This is to limit the activities during the experiments and ensure the research based on fixed items. The items that been fixed were assembled according to Figure 2 below.

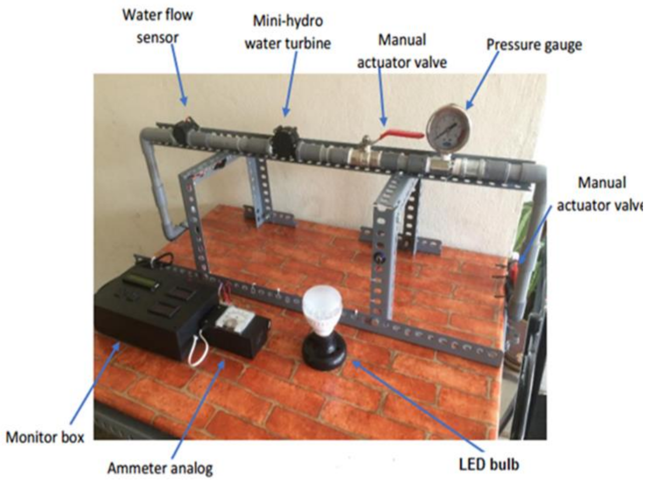

Figure 2: Residential piping designed system

The Arduino application was then designed and programmed for the monitoring box as shown in Figure 3.

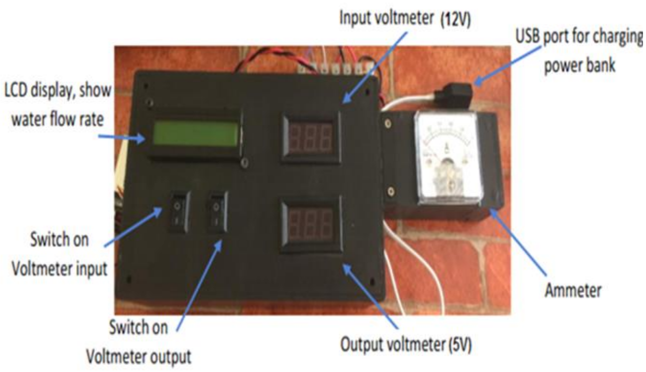

Figure 3: Monitor box

The items used for the evaluation and assessment criteria are defined as follows.

A. *Piping diameter*

In this assessment, only two types of PVC (Poly Vinyl Chloride) piping diameters were evaluated, which covered ½ inch and ¾ inch. The two diameters were assessed to understand the electrical performance towards the water pressure versus the electrical performance. Table 1 shows the comparison for the piping in terms of dimension.

Table 1
PVC Piping Diameter comparison

PVC Profile	Actual Outer Diameter	Actual Inner Diameter
 1/2"	0.84 inch	0.622 inch
 3/4"	1.05 inch	0.824 inch

The ¾ inch PVC profile has larger inner and outer diameter compared to the ½ inch size and both were tested to understand their performance towards the flow rate and electricity performance.

B. *Piping length*

The piping length was measured and cut accordingly to the defined length before they were assembled in the system. In this assessment, there were two lengths involved, in which the minimum was 26 inch and the maximum 52 was inch. This is to understand the effect of PVC length towards the electrical performance.

C. *Water flow rate*

Two water flow rates have been identified for this assessment, which covered 220 Liter/Hour and 580 Liter/Hour. The water flow rate measurement was based on the water flow sensor, which was linked with Arduino Uno and Liquid Crystal Display (LCD) to display the real time water flow rate. The 580 Liter/Hour was defined when the water tap valve was opened to the maximum resulting to more water flow, which indicated the LCD to a reading of 580 Liter/hour. While 220 Liter/hour was based on the minimum water tap valve opening, showing that the power bank is still in charging mode. This is to evaluate the minimum requirement for the system to be working.

D. *Hydro water turbine*

The turbine was used to produce 12V, which was then converted to 5V to charge the power bank. It depends on the water flow rate and pressure to produce the charging level.

E. *Water flow sensor*

The water flow sensor was used to monitor the water flow rate that was pumped in the PVC piping. Two water flow rates were evaluated, and they covered the minimum flow rate 220 Liter/Hour and the maximum rate of 580 Liter/Hour. The sensor detected the flow and did the calculation.

F. *Monitor Box*

The monitor box created in this project consisted of the Arduino UNO card, which was connected to LCD and the water flow sensor. The monitor box helped to display the water flow rate, input voltage and the output voltage produced.

G. *Power bank*

A 4000mAh power bank was used in this assessment to understand the charging time purpose. The use of smaller capacity fastened the charging operation to achieve fully charged battery condition with lower charging time.

H. DC – DC Buck converter

A buck converter or step down converter was used to step down 12V to 5V for charging the power bank purpose. This was because the application was according to 5V voltage input.

I. Data collection method

Electrical output performance data were collected manually at one-minute interval for 30 minutes to achieve 30 data per run and average data used.

III. RESULTS

The design of experiment (DOE) was to understand the factor that affected the electrical performance. There were eight runs during the DOE, which involved three factors, such as the water flow rate, the diameter of PVC piping and the piping distance on each connection. There were minimum and maximum value setting for each factor. For the water flow rate, the minimum value was 220 Liter/Hour and maximum value was 580 Liter/Hour. The diameter for the PVC was defined with a minimum value equals to ½ inch and maximum value equals to ¾ inch. The final factor was the piping distance with a minimum value of 26 inches and maximum value of 52 inches. The simulation results are presented in Table 2 below. Based on Table 2, 0 represents the minimum value, while 1 represents the maximum value.

Table 2
Simulation results

No of runs	Flow rate (L/Hour)	Diameter (inch)	Piping distance (inch)	Average Output Voltage (V)	Average Current (A)
1	0	0	0	3.50	0.02
2	0	0	1	3.38	0.02
3	0	1	0	3.38	0.02
4	0	1	1	3.35	0.02
5	1	0	0	4.39	0.1
6	1	0	1	4.37	0.1
7	1	1	0	4.35	0.1
8	1	1	1	4.34	0.1

Based on the results, it can be concluded that water flow rate plays a vital role to achieve higher voltage value. The maximum flow rate gave higher voltage value, while lower flow rate gives lower value. The diameter of the piping gives a small impact towards the generated voltage. A bigger diameter (¾ inch) of PVC piping produces slightly higher voltage value compared to smaller (½ inch) diameter of PVP piping. However, this condition exists when the maximum flow rate is applied to the system. The same results were observed for the piping distance, which showed longer piping distance provides slightly higher voltage value. By having all the factors with maximum value, the results showed that the system produces the highest voltage results.

Since the water flow rate provides the biggest impact towards the voltage performance, the water flow rate was then evaluated further to understand the behavior towards voltage performance. The piping diameter and piping distance were fixed at a maximum value to get higher output, showing the same results as Benedicto N. Fortaleza [9]. The water flow rate was then measured by using water flow sensor to understand the pressure involved and the results are shown in Figure 4.

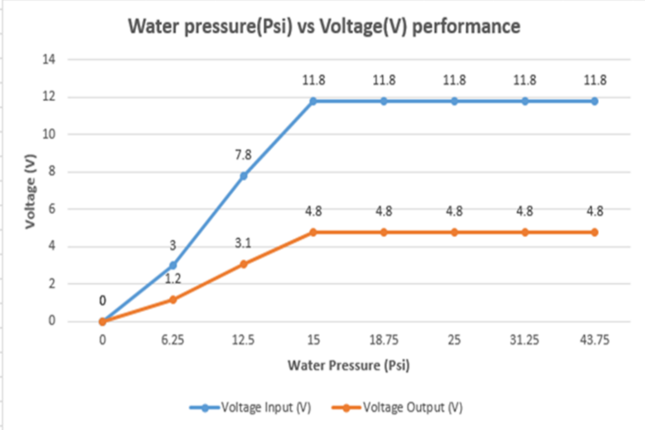

Figure 4: Water pressure vs voltage performance

Two output voltages, covered for 5V and 12V were monitored in this analysis. The incoming voltage 12V was monitored at the turbine output, while the 5V output was monitored after the DC-DC buck converter step down process. The results showed that the higher the water pressure, the higher the voltage produced. However, at one stage of the water pressure, the voltage becomes constant for both at the water turbine and the DC-DC buck converter. As shown in Figure 4, we can see that at 15 psi and above, the generated voltage becomes constant at 11.8V and DC-DC buck converter results showed that the output is stabilized at 15 psi as well producing 4.8V for the purpose of charging the power bank.

The Arduino was used to convert the water pressure from psi to liter per hour (L/H) by programing. Its purpose is to determine the sufficient water volume for the system that enables the charging of the power bank. The conversion results showed that with minimum water flow rate of 250 L/hour, the system started to charge the power bank consistently at a constant 4.8V voltage output. At 220 L/hour, the charging process occurred but intermittently due to instable voltage output produced. The water flow rate versus voltage generated can be referred to Figure 5 below.

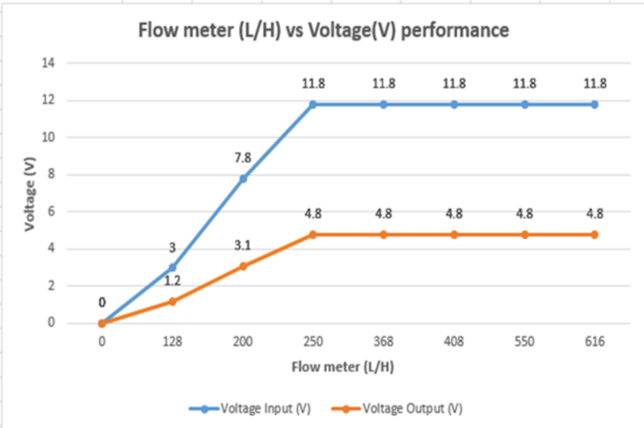

Figure 5: Flow meter vs Voltage performance

To understand the charging time by the turbine towards the 4000 mAh powerbank, a data was collected to understand the performance. The powerbank had been left uncharged and the 15 psi water flow had been fixed for the purpose of determining the charging time performance. The results are presented in Table 3.

Table 3
Charging time monitoring results

Charging Time (minutes)	20	40	60	80	100	120	140
Powerbank battery charging indicator level (%)	15	30	40	60	70	85	100

The results showed that 140 minutes charging time is required to fully charged the 4000 mAh powerbank. However, this is the condition when the powerbank is in fully discharged condition.

IV. CONCLUSION

This paper provides an information on the possibility to have renewal energy from the residential area through water piping system. The Arduino has application successfully provided real time voltage and current, including water flow rate monitoring towards the system operation. From the analysis, the factor required to generate higher voltage are maximum water pressure (> 15 Psi), bigger piping diameter and shorter piping distance. From the optimization conducted, the final piping design successfully has charged the power bank and lighted up the 5V LED bulb with a minimum of 15 Psi of water pressure or 250 L/H in terms of water flow rate. The water flow rate plays a vital role towards current performance, in which higher flow rate provides higher current value. However, once the water flow rate reaches 250 L/H the voltage is saturated at 11.8V and 4.8V accordingly. If the powerbank is fully discharged, the system requires 140 minutes to make it fully charged and the time is considered acceptable. This study has significant impact towards developing an alternative method for existing renewable energy by successfully designing the new concept of residential piping system.

ACKNOWLEDGMENT

We would like to express our gratitude towards Universiti Teknikal Malaysia Melaka (UTeM) for the opportunity to accomplish this project under the institution at Faculty of Engineering Technology.

REFERENCES

[1] Budiarso, Warjito, M. Naufal Lubis, and D. Adanta, "Performance of a low cost spoon-based turgo turbine for pico hydro installation," in *Energy Procedia,* 2019.

[2] E. Chica, F. Pérez, and A. Rubio-Clemente, "Rotor structural design of a hydrokinetic turbine," *Int. J. Appl. Eng. Res.*, 2016.

[3] M. F. Basar, A. Ahmad, N. Hasim, and K. Sopian, "Introduction to the pico hydro power and the status of implementation in Malaysia," in *Proceedings - 2011 IEEE Student Conference on Research and Development, SCOReD 2011*, 2011, pp. 283–288.

[4] J. Macknick, S. Sattler, K. Averyt, S. Clemmer, and J. Rogers, "The water implications of generating electricity: water use across the United States based on different electricity pathways through 2050," *Environ. Res. Lett.*, vol. 7, no. 4, p. 045803, 2012.

[5] B. N. Fortaleza, R. O. Serfa Juan, and L. K. S. Tolentino, "IoT-based Pico-Hydro Power Generation System Using Pelton Turbine," *J. Telecommun. Electron. Comput. Eng.*, 2018.

[6] Y. A. Badamasi, "The working principle of an Arduino," in *Proceedings of the 11th International Conference on Electronics, Computer and Computation, ICECCO 2014*, 2014.

[7] International Renewable Energy Agency, *Renewable Power Generation Costs in 2017.* 2018.

[8] H. Zainuddin, A. Khamis, M. S. Yahaya, M. F. M. Basar, J. M. Lazi, and Z. Ibrahim, "Investigation on the performance of pico-hydro generation system using consuming water distributed to houses," *Int. J. Electr. Comput. Energ. Electron. Commun. Eng.*, vol. 3, no. 11, pp. 1–4, 2009.

[9] M. M. S. R. S. Bhargav, V. Ratna Kishore, S. P. Anbuudayasankar, and K. Balaji, "Power generation by high head water in a building using micro hydro turbine—a greener approach," *Environ. Sci. Pollut. Res.*, 2016.