Available online at www.sciencedirect.com

ScienceDirect

Procedia - Social and Behavioral Sciences 129 (2014) 198 – 205

Procedia
Social and Behavioral Sciences

ICIMTR 2013

International Conference on Innovation, Management and Technology Research, Malaysia, 22 – 23 September, 2013

Preliminary Design of a Mini Hydroelectric System

Mohammad Azzeim Mat Jusoh[a]*, Muhamad Fauzi Othman,[b] Zubli Quzairov Zubli,[c] Mohd Hafiz Bin Mohd Noh,[d] Ahmad Hussein Bin Abdul Hamid[e]

[a,b,d,e]*Fakulti Kejuruteraan Mekanikal (FKM), Universiti Teknologi MARA (UiTM), Shah Alam, Selangor, MALAYSIA*
[c]*Tenaga Nasional Berhad (TNB), Kuala Lumpur, MALAYSIA*

Abstract

Renewable energy is a common topic that has been discussed continuously since the past few decades. The process of generating and restoring energy needs to be developed, without neglecting the effect towards the environment itself. As for this research, the basis is to verify a concept; whether the fluid motion in normal pipeline; is able to be utilized and converted into sufficient electrical output or not. In this concept, each time the user runs the taps, the water flow shall initiate the system by moving the inner mini blades and convert rotational motion to the shaft, which links to the DC generator. The changes from kinetic energy shall then be converted to electrical energy, which shall be preserved for later use. As a result, this system is able to provide an economical way to produce electrical energy without affecting the environment.

Selection and peer-review under responsibility of Universiti Malaysia Kelantan

Keywords : Hydroelectric, Renewable Energy, Mini Water Turbine, Computational Fluid Dynamics (CFD), Flow Rate, , Computer Aided Design (CAD),

1. Introduction

In general, the average electrical consumption for a single house could reach until 300 to 400 kWh per month, which can be considered high in long-term specification. At the same time, some of the potential power source such as the water flow in the pipeline is normally being left wasted without being fully used. The problem is, such device is not available especially for domestic in-house use. Considering the

* Mohammad Azzeim Mat Jusoh Tel.: +603-5541 1823; fax: +603-5543 5160.
E-mail address: m_azzeim@salam.uitm.edu.my

Selection and peer-review under responsibility of Universiti Malaysia Kelantan
doi:10.1016/j.sbspro.2014.03.667

demand for a greener environment, the urge to create an environment friendly, which could utilize the potential of this energy, is very much needed.

The main obstacle here is to validate on the performance of this system, whether the potential force of the water flow is able to produce sufficient output for the minor use of a normal household or not. For this reason, related experimental procedure should be taken in order to validate the performance. At the same time, limitations should be studied and highlighted in order to ensure that the system does not have any drawbacks that could affect the normal performance of water flow.

2. Literature Review

Based from the report of the Energy Information Administration (2007), Malaysia has approximately 16 GW of electric generation capacity, which consists of 87% thermal and 13% hydroelectric. Due to the emergence of energy shortage and the potential for depletion of fossil energy, humans have to adjust energy structure dominated by oil towards a structure of diversified energy sources, and start to develop and utilize new and renewable energy, such as solar, wind, ocean, biomass and geothermal energy (Chen, 2010). These tendencies will continuously becoming a major revolution in energy technology.

Hydropower is one form of the energy that could be managed especially from water sources such as the ocean, rivers and waterfalls. Small-scale hydropower is one of the most cost-effective and reliable energy technologies to be considered for providing clean electricity generation. One of the obstacle here is that, even a basic application of renewable energy in Malaysia consume hundreds millions of ringgit especially for large-scale project. However, recent research shows that it is possible to harness energy in small sum of water flow, with the conditions that the resource is continuous and abundant. Based from the Global Status Report (2012), the usage of Pico water turbines in countries such as Africa is popular, especially in rural areas that have small river running near their houses. These turbines have been assembled in order to generate ‘free’ electricity without needing to rely on other resources. With high efficiency up to 70%, small-scale hydropower is by far is one of the best option for cost-effective renewable energy (Winebrake, 2003).

Theoretically, Bernoulli’s energy equation is one of the main references (Cengel, 2011). In general, the speed remains constant at inlet and outlet of turbine, including pressure. Thus, mechanical energy delivered by the turbine is due to the height difference of the system. The power is proportional to the product of head and flow rate (Refer Eq. 1). This concept is closely related, by fully utilizing natural energy from the supply. Next, the fabrication of the mini hydroelectric shall not complete without the DC generator. The main function is to generate electricity, as water shall flow continuously and rotates the blade inside the device. For this reason, Faraday's Law (Wildi, 2006) shall be used as reference in order to monitor the performance of the DC generator (Refer Eq. 2).

$$H = z + \frac{p}{\rho g} + \frac{v^2}{2g} = h + \frac{v^2}{2g} \quad (1)$$

$$E\text{o} = \frac{Zn\Phi}{60} \quad (2)$$

3. Research Methodology

The very principle of this invention is to harness the water pressure in the pipeline to propel the water turbine. As the water turbine turns, it turns the shaft, which is connected to the DC generator. The DC generator shall then convert the kinetic energy into electrical energy. The overall process shall be monitored through the Experiment Flow Chart (Refer Fig 1).

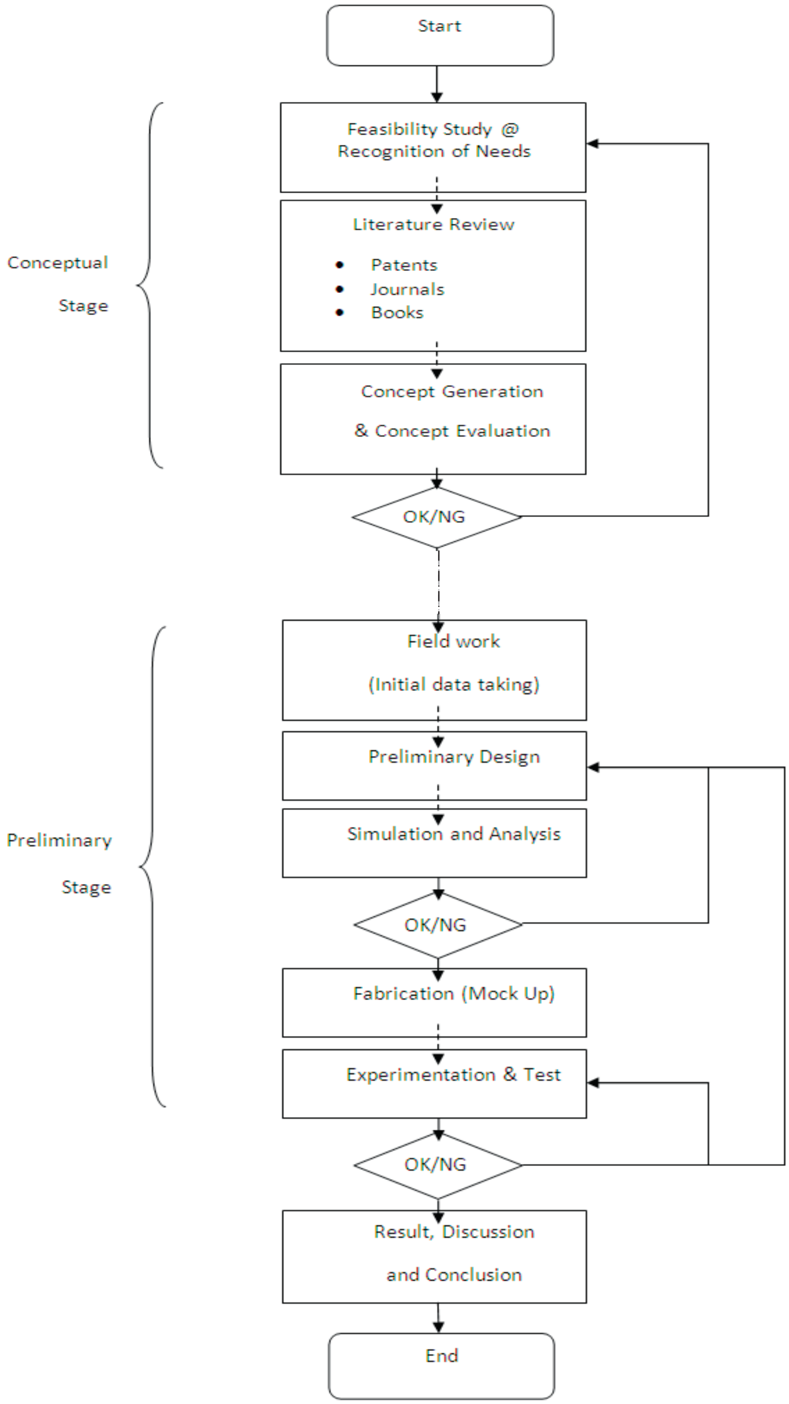

Fig. 1: Experimental flowchart

Fig. 2: Basic piping layout in a normal household

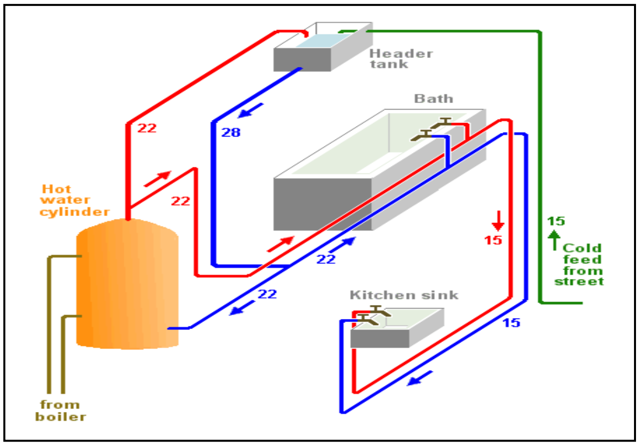

Fig. 3: Piping layout based on size and water temperature

3.1 Conceptual Design Stage

Based from Shigley (2008), the methodology of the project can be divided into three main stages. The first stage involves the conceptual stage or feasibility studies. As the name implies, a feasibility studies is the analysis of the viability of an idea. All related activities are focused toward gathering data and information from references such as books, conference papers, journals, patents and others. For example, the related references for the piping system in a normal household is shown in Fig 2 and 3 (Zulkifli et al., 2008; Hearfield, 2012). Finally, all the information and concept gathered shall be summarized according to its respective categories.

3.2 Preliminary Design Stage

The second stage mainly involves fieldwork. Sample of flow rate, head and velocity of household pipeline shall be taken and analysed. Next, the design of the product shall be shortlisted. Using Pugh Chart as basis, each of the design shall be evaluated according to relevance. After selecting the best design concept, detail design must be considered. The detailed design shall be drafted and improved using CATIA software using the actual dimension. Later on, simulations shall be conducted according to the specified requirement.

Next, a prototype shall be fabricated according to the design spec, and shall be tested accordingly. For our design, the pipes, shaft and DC generator shall be procured based on standard and compatibility factor. As for the blade, it shall be made custom using rapid prototyping technology (Refer Fig 4). The material selection process for the product is very important in order to ensure that it is suitable for the system, and can withstand the maximum load applied. Basically, PVC and PC material have been chosen as the material for the main part, which is the pipe and blades.

Next, the Hydraulics bench (Refer Fig 5) shall be used during the experiment in order to the performance of the Mini Hydroelectric. The flowrate needs to suit the general application in a normal household (from 0.2 liter/s and above). The DC motor shall be connected to the LED in order to monitor the power output of the product. Using a multimeter, the result shall be recorded with relevance to each specified flowrate.

3.3 Data Analysis

The final stage is to analyse and evaluate the overall recording of the experimentation. During this stage, the result of calculation, simulation and analysis/experimentation result shall be reviewed. Results shall be discussed accordingly and conclusions plus recommendation shall be made.

Fig. 4: Rapid prototyping machine Invision XT 3-D Modeler

Fig. 5: Hydraulics bench F1-10

4. Result

4.1 House Water Tank Experiment

The house water tank experiment has been conducted in order to identify the average water flow rate in a normal household. As a procedure, the time required to fill the 1.0 liter container needs to be measured and summarised. Next, the mock up sample is being placed 0.3 m below the water tank. As a result, the result shows that the average water flow rate from the water tank is 0.256 liter/s. However, in order to fulfill the requirement for a quiet flow rate system for a 15mm radial pipe, the value of 0.3 liter/s shall be used as the main reference especially in terms of calculation and evaluation (Hearfield, 2012).

4.2 Comparison between the Conceptual Design and prototype sample.

The Mini Hydro was built by incorporating three major components, which is the pipe, the blade and the DC generator. The blade was attached to the pipe by sliding a shaft between it and the pipe. This particular shaft is link onto the DC generator. A metal frame has been adapted in order to increase the stability of the DC motor. Comparison can be made between the conceptual design and the improved version by referring to Fig 6 below.

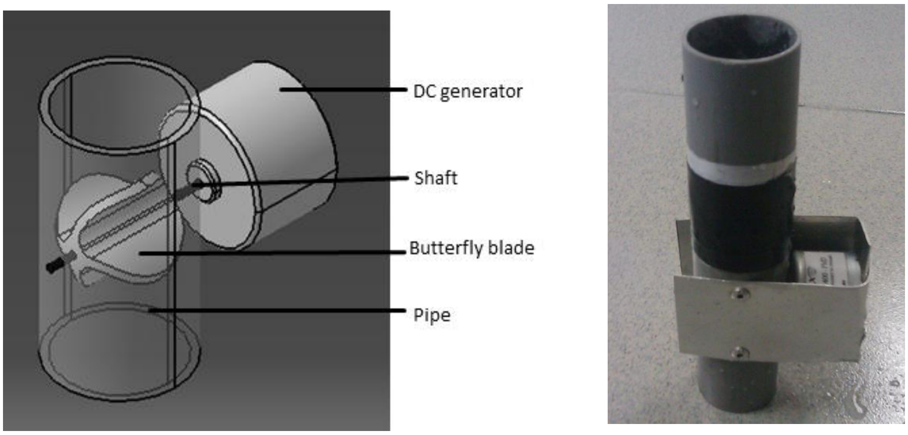

Fig. 6: Comparison between (a) Conceptual design and (b) Prototype

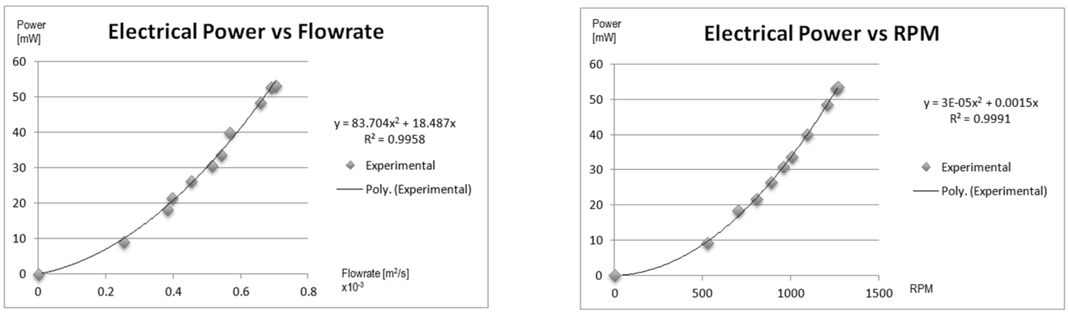

Fig. 7: Experiment result (a) Electrical power vs flowrate and (b) Electrical power vs RPM

4.3 Experimental Result

The experimentation has been conducted by using the hydraulic bench as the main apparatus. The data has been plotted in order to justify the performance of the product. As a result, using the 15mm radial pipeline as basis, the minimum and maximum water flow rate is around $0.254x10^{-3}$ to $0.73x10^{-3}$ m^3/s. Eventually, the system can only perform beginning from this minimum value, after managing to exceed the minimum load of the DC generator. Whereas, the maximum flow rate was due to the limitation of the hydraulic bench.

Fig 7 shows that the power output is proportional to the flowrate, and also rpm of the product. The equation shows a positive increment, and shall be used as datum for the future experimentation. Unfortunately, the potential of the DC generator cannot been fully explored. According to specification, the DC generator is capable in achieving 2,400 rpm. Whereas in this experiment, we could only achieve only half of the result, which is around 1,265 rpm. In near future, by concentrating on the optimization factor of the DC generator and the design, a better and positive result could be achieved.

The flow rate result can be used to understand the basic behaviour of fluid in normal pipeline, in order to generate electricity. The fact is, fluid flow in a normal pipeline always behaves in a turbulent manner and difficult to control. The main reason in determining pipeline size is actually more towards suiting consumer usage. This is done by increase the flowrate, at the same time reduce any side effect such as vibration and noise. Fundamental theory and engineering knowledge is sometime irrelevant in real cases. The final judgement and decisions needs to be made by us human, based on trial and experience.

Our initial objective is to operate the product below the quiet flow rate specification, which is 0.3 liter/s. However, if we refer to result in Fig 7, this condition can only fit the minimum requirement of this system, or more specifically the specification of the DC generator. In order to solve this problem, one of the solutions that can be made is to apply this in a higher flow rate environment, such as the 22mm radial piping size and above. Also, a better solution is to adapt the system onto the main external pipeline, where the pressure is much more higher (in average around 2 bar).

5. Conclusion and Discussion

The main objective of this research has been achieved, which is to validate the concept of this product in a normal household environment. Eventhough there are some limitation and obstacles, solutions have been proposed and discussed in a positive manner. Using this design as foundation, we are positive that in near future, the contribution of this product towards supporting green technology is far more beneficial compared to the minor problem, which is solvable by careful study and improvement.

Acknowledgements

This project was managed with the funding from Dana Kecemerlangan Pendidikan (Reference No: 600–RMI / DANA 5 / 3 / RIF (120/2012)). The author would like to thank RMI (Research Management Institute) and also the Faculty of Mechanical Engineering (FKM) of UiTM Shah Alam for the facilities and financial support. Not forgetting, the strong and enthusiastic effort of young team members such as Zubli Quzairov, Nik Hosni Iskandar and Ashraf. All the best for your career and future life.

References

Administration, E. (2013). Energy profile of Malaysia. Retrieved from http://www.eoearth.org/view/article/152509

Chen, Y., (2010). *Energy Science & Technology In China: A Roadmap To 2050*. Heidelberg Dordrecht London New York: Springer, (Chapter 2).

Winebrake, J.J., (2003). *Alternate Energy: Assessment & Implementation*, Book CRC Press, (Chapter 1)
REN 21, (2012). *Renewables 2012 Global Status Report* (Paris REN21 Secretariat).

Cengel,Y.A., Cimbala, J.M.,(2006). *Fluid Mechanics; Fundamentals and Applications.* McGraw Hill, (Chapter 5).

Wildi, T. (2006). *Electrical Machines, Drives, And Power Systems* (5th ed.). Pearson Prentice Hall, (Chapter 2).

Richard G. Budynas, J. K., (2008) *Shigley's Mechanical Engineering Design.* McGraw Hill, (Chapter 1).

Zulkifli, M.S., Zainal, A.R., Tuslah, A., (2008). *Kemahiran Hidup Bersepadu Tingkatan 1* (pp. 66). Cerdik Publication Sdn Bhd

Hearfield, J., (2012) Domestic Water Supply. Retrieved from http://www.johnhearfield.com.