Recovery of KE & PE of Flowing Water

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***Abstract*—This project aims to harvest the energy of flowing water. Through the use of a water turbine and a hydroelectric generator, the kinetic and potential energy of water can be converted into electrical energy and stored for future application.**

***Index Terms*— Energy Harvesting, Hydroelectric, Water Turbine, Generator.**

I. INTRODUCTION

Hydroelectric power is energy harnessed from water flowing at high velocity (kinetic energy) and water flowing from a greater height to a lower height (potential energy). When water pushes the blades in a turbine, kinetic energy is converted into mechanical energy. The turbine in turn spins the generator rotor which then converts mechanical energy into electrical energy. Hydroelectric power is a green and renewable source of energy as it does not pollute the water or the air, it may be use for a multitude of applications.

A. Context

In Singapore, there are over 8000 high rise buildings [1]. These buildings have water tanks placed on the top to serve its residents. This project intends to harvest the energy of the water stored in the water tanks to generate electricity. By building a scaled-down turbine and generator as a prototype, it can be implemented to make a Housing and Development Board (HDB) block a smart, sustainable and green building. This will work well in addition to the installed solar panels on the rooftops of blocks managed by West Coast and Choa Chu Kang Town Councils [2].

The average HDB household monthly water consumption for a 5-room flat is 18.6 Cubic Metre [3]. This equates to 620 litres of water per day. Considering a HDB block has around 10 units per block and 20 floors, the total daily water usage of the entire block is 124 Cubic Metre. This is a large amount of energy from flowing water that is going down the drain if it is not harvested.

B. Placement consideration

The placement of the water tank is crucial as it affects the flow of water. There are two considerations which were accounted for - water pressure and constant water flow. The placement marked with the cross in Fig 1.1 will result in the highest water pressure and but least constant water flow as water usage from the higher floors will not spin the turbine.

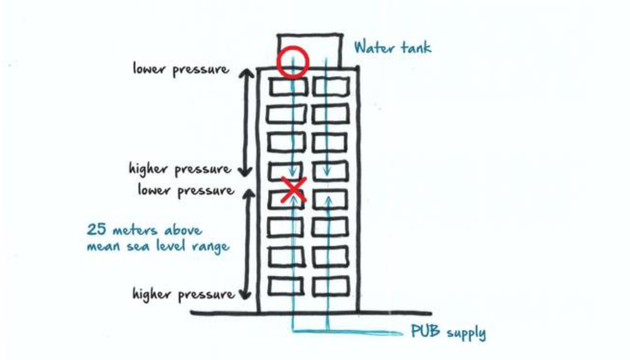

Fig 1.1 Typical water flow layout of a HDB block with the considered placements of the hydroelectric generator

Therefore, this project aims to install the hydroelectric generator at the mouth of the water tank, circled in Fig 1.1. This will allow a higher constant flow of water as water usage from all floors serviced by the water tank will induce a flow in the main water supply causing the turbine to spin but at the cost of a low water pressure. A clearer picture of the intended placement can be seen in Fig 1.2.

Fig 1.2 Water tank on the rooftop of a HDB block with intended placement of hydroelectric generator

C. Application

Currently, the corridor lights of HDB blocks are on from 7pm to 7am the next day. A lot of energy is utilised to power the lights. If energy can be generated from the flow of the main water supply and stored during peak times, this stored energy can be used as the main source of power for the corridor lights. Thus, the main application of this hydroelectric generator is to store the electricity in a main battery storage and power the corridor lights of a HDB block. Ideally, each floor would have a generator and generate sufficient energy to light up the corridor lights of the entire floor. However, this project will only focus on building a single hydroelectric generator.

Additionally, the stored energy can also be used to power vital equipment in times of emergency. During a blackout, the energy can be used to power passenger lifts and emergency exit signs. In the future, the project would like to generate enough energy to charge smart electric cars parked under the block.

II. MECHANICAL DESIGN

There are two main types of water turbine designs, namely the impulse and reaction turbines [4]. In an impulse turbine, there are stationary nozzles which are directed towards the turbine blades such that water flow is directed to spin the blades. Conversely, reaction turbines do not have stationary nozzles. Both pressure energy and kinetic energy of the flowing water through the nozzles contribute to the rotation of the turbine.

A. Design consideration

Due to the context of the application, the group has decided to adopt the impulse turbine design as seen in Fig 2.1. Since the intention is to allow the water to flow to spin the turbine, the blades are oriented in a non-angled manner which is similar to a water wheel so as to maximise the contact area of the blade with the flowing water.

Fig 2.1 Four-bladed impulse water turbine

B. Design layout

There are three main layers to the design - water turbine, coils and magnets. First, a metal can is used as the housing and base of the system. As previously explained, an impulse turbine requires stationary nozzles. As such, two holes are drilled for water flow.

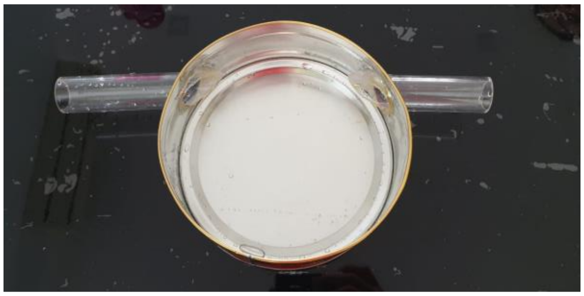

Fig 2.2 Base of the system

Next, an acrylic board is used as a cover and acts as a separation layer for the wet components from the dry components. Subsequently, a layer of solenoid coils are placed on top of the turbine. This layer is not meant to be spun as it was not desirable to tangle the wires when connected to external circuits. Three pairs of neodymium magnets are placed on a separate layer that is above the solenoid coil layer. The idea is to allow the central rod to spin via the rotating rod and that will spin the magnets. A ball bearing is placed in between the solenoid coils and magnets layers to stabilise the rotating central rod and prevent the solenoid coils from spinning. Fig. 2.3 shows the fully assembled mechanical setup.

Fig. 2.3 Actual mechanical setup

III. CIRCUIT DESIGN

A. Electrical components

Components	Quantity
Solenoid coil (500 turns)	3
Neodymium magnet	6
Rectifier diode	6
Voltage regulator	1
LED	1

B. Electronic circuit design

The electronic circuit design consists of 4 main parts, including the power sources (induction coils), rectifier circuit, voltage regulator and application or power storage.

Induced current generated by rapidly spinning permanent magnets is the power input source for this device. Depending on the layout of magnets and coils, the current input can be in different phases. The above electronic circuit is design based on a 8V 3 phase power input, with a 3 phase rectifier circuit to convert AC signal to DC signal, which can be use to power other appliances.

A voltage regulator is included into the circuit to stabilize and step down power source. It acts as a safety device to prevent electrical damage to any appliances. An external 5V or 1.5V rechargeable battery can be used to store the generated power from this device.

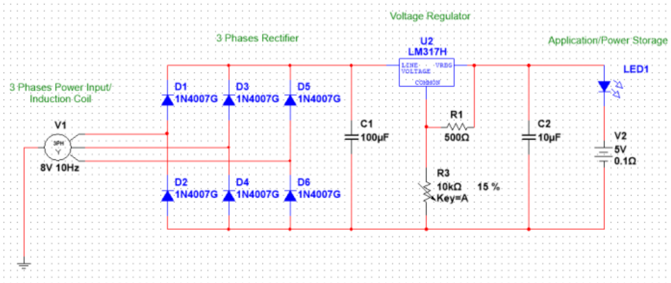

Fig. 3.1 Schematic design of electronic circuit

IV. PROTOTYPE TESTING

First, the group decided to test the mechanical and electronic systems separately to ensure that both systems are working correctly on their own.

A. Mechanical testing

Water flowing through the inlet spun the turbine albeit at a relatively low angular velocity. A manual spinning shaft test is conducted to ensure the structural integrity is within the acceptable range.

B. Electronic testing

The current setup is only capable to induce a single phase power input due to the physical layout of magnets and coils. All electronic tests are done based on single phase input.

The electronic circuit design is simulated on the National Instrument Multisim software to ensure it provides desired functionalities. The physical electronic circuit is tested by using 2 function generators which are capable to output 2 channels power sources with each as a stable input. The output signal is captured using an oscilloscope. A schematic testing setup is shown in Fig. 4.1.

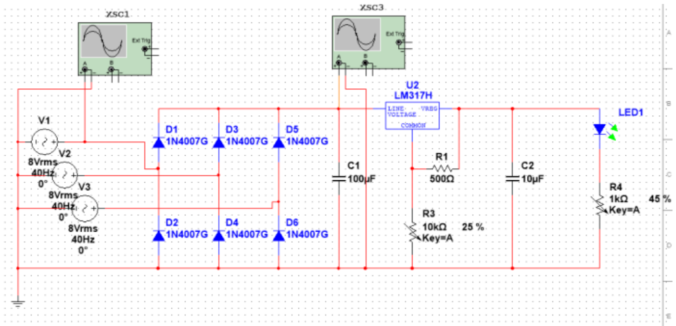

Fig. 4.1 Testing setup with oscilloscopes

Due to low voltage generated, voltage regulator (L7806CV) cannot be operator under this circumstances. Thus, the signal after voltage regulator is excluded in the test.

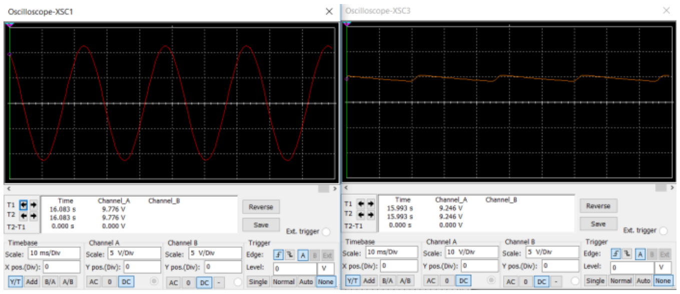

Fig. 4.2 Voltage signal of testing setup Fig. 4.1

An induced EMF test is conducted by manual spinning of the shaft with the presence of magnets and single coil. The result is shown in Fig. 4.3. Voltage across the one of solenoid coil is roughly $3V_{pp}$. All pre-coil solenoid coils has to be ensured that none of them is broken.

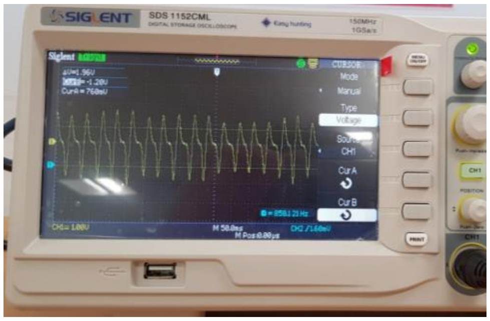

Fig. 4.3 Manual spinning signal output

A fully assembled setup with electronic circuit is shown in Fig. 4.4.

Fig. 4.4 Prototype testing setup

Fig. 4.5 Channel 1 (yellow): voltage across solenoid coil (V_{pp} = 2.5V), channel 2 (blue): voltage after rectifier (V = 1.2V)

As seen in Fig. 4.5, there are 2 orange arrows and 1 green arrow. The orange arrows signifies the voltage generation due to the change in the magnetic field. However, it is noted that there is a plateau between the 2 orange arrows. This can be explained by the physical distance between each pair of magnets. Due to the distance, there is a period whereby the coils do not pick up the change in magnetic field, hence, the plateau.

Conversely, the green arrow shows that the sine wave first hits a trough before progressing to a peak. This means that the third magnet pair has different magnetic pole directions compared to the first two pairs of magnets.

V. FUTURE IMPROVEMENTS

There are a few improvements to the system that the group has considered from both mechanical and electronic point of view.

A. Mechanical

The group expects that increasing the number of blades from four to six may yield a higher power output. As such, a second prototype with a 6-bladed turbine may be fabricated if time permits.

A flywheel is also considered so that the turbine continues to spin even if there is no water flowing. This is to maximise the kinetic energy of the turbine so that more power can be generated. Based on the initial test of the prototype, it was noted that the turbine spun at a low angular velocity. Thus, it is desirable to increase the angular velocity.

Gears are a possible add-on so that the revolutions per minute (RPM) can be increased. However, since the turbine is fabricated out of acrylic, a balance between speed and the integrity of the turbine must be struck.

B. Electronic

Another idea is to increase the number of coils from 3 to 6 per layer so that there is a larger magnitude in the induced electric field. Additionally, another layer of 6 coils can be introduced to the design to increase power output. By introducing more coils, a 3 phase power source can be obtained to increase power output while keeping the cost of device reasonable.

Distance between each magnet needs to be decreased to ensure a stable sine wave input. This can be achieved by adding more magnets into the array, for example 6 or 9 in a cyclic layout.

Furthermore, the voltage regulator can be excluded due to low voltage input (below 10V) of the setup. However, a higher capacitance is required for the rectifier circuit. The group also plans to implement safety functionalities into the electronic circuit such as a fuse and power storage overcharge prevention.

VI. CONCLUSION

Over the first half of the semester, the group has managed to fabricate a working design of the hydroelectric generator as well as to test the prototype. In the second half of the semester, the group hopes to improve on the output of the setup through its mechanical and electronic components.

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