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Prototype of electrical generator development based on water flow pressure

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ABSTRACT

Electric potential energy or kinetic energy produces electrical energy. The integration of electrical current and potential yields the energy that is deliverable to the end user via electrical circuitries. There are various techniques used to produce electric energy. Typically, electricity is generated by using fossil fuels or natural gas. However, these resources are facing the extinction problem. Thus, another established method to generate electricity is by using water flow pressure in hydroelectric station. This work presents a model of small electrical generator developed based on the theory of pressure yielded by water stream. The development of conventional hydroelectric generator station destroyed the nature environment and caused the death of animal, especially in the water. Therefore, a turbine in a spherical shape that is integrated with microcontroller is suggested in this work with external passage that is attached to the turbine to reduce the catastrophic effect to the aquamarine and nature. The analysis is conducted on the different material while designing the basin, size of basin radius and the structure of model outlet inlet. The results show that the turbine that is designed by using polyvinyl chloride (PVC) with 10 cm radius produced higher voltage at 5.8 V compared to the other types of basin material and radius.

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1. INTRODUCTION

Electricity is one of the important energies in life. It plays a big role in daily life. Various resources had been used to produce this energy either via solar panel [1], nuclear [2], hydroelectric [3], petroleum/fossil fuels [4], ocean wave [5], geothermal source [6], wind turbine [7], and natural gas [8]. The power generating technique is unalike between each country since they have different supply resources. In developed countries such as China, India, France, the United State of America, Germany, Canada, and United Kingdom, the wind system is used as one of the main sources of their electric power.

In Malaysia, electric energy is generated by using fossil fuel, solar panel and water flow pressure in hydroelectric station [9]. The usage of fossil fuel such as coal and natural gases to produce electricity is facing the resource extinction problem. It is difficult to obtain the replacement of this resource. International Energy Efficiency reported that in 2014 and 2015, fossil fuels generate 80% of the total world primary energy. It causes the increment of global greenhouse gas (GHG) emission intensely [10]. It is also expected within these coming 30 years, the fossil fuel combustion will increase the world GHG emission from 54 Gt CO2-eq to 70 Gt CO2-eq [10]. In addition, the cost of the maintenance of this system also getting higher because of these limitations [11]. Therefore, because of these reasons, the world needs another resource to obtain electricity energy.

Solar panel is an alternative method to produce electricity [12]-[15]. Though, the operating cost is higher and require high maintenance. Another technique that is widely used to produce electric energy is by using hydroelectric generator station. Various techniques are implemented to operate the generator station such that the optimum energy is produced [16]-[19]. Several aspects of the system need to be considered in order to allow the maximum output will be produced. Each component of the system will contribute to the effectiveness of the output. Thus, a proper consideration between each part is essential since the specification of each component will influence the efficacy of the other part.

The process of generate electricity by using water flow to drive a turbine and produce the powers to the generators is called as hydroelectric. Electricity in the hydroelectric station is made by generators that are pushed by water movement. A reservoir to collect water in a river to been pumped is developed with dams that block a river. When the water is released from the dam, it will be forced down through the pipes by a high pressure behind the dam and lead to a turbine. This process is called as hydropower. Dam and reservoir system are the basic concept that is related with conventionally hydroelectricity. Generally, it is a system that divert water flow to generate power and often can impound water [20]. 16.6% of the world’s total electricity is generated by hydropower in 2015. 70% of all renewable electricity is also produced by hydropower. These figures are expected to increase by 3.1% per year until 2050.

Dam is the main part of the hydroelectric power plant. It acts as the water reservoir. Kinetic and potential energy is yielded by the water flowing in the river. The plant then converts the energy into electric energy. The basic parts of the power plant are dam, water reservoir, control gates, penstock, water turbine and generator. The dam should be constructed on a large river which has plentiful quantity of water throughout of the year. In order to obtain the maximum potential energy from water, the location to build the dam need to be choosed such that the height of the river is suitable to produce optimum energy. The water is stored in the water reservoir which is placed behind the dam. It is located higher than the rest of the dam structure. The control gates which will release and control the flow of water from the reservoir is built on the inside of the dam. The long pipe that carries the water flowing from the reservoir to the power generation unit is called as penstock. The power generation unit consists of turbine and generator. The electricity is produced in the generator. The rotation of the shaft of the water turbines in the generator produce the alternating current in the coils of the generator. The magnetic field produced by the rotation is then converted into electricity by electromagnetic field induction. The basic components of hydroelectric power plant are illustrated in Figure 1.

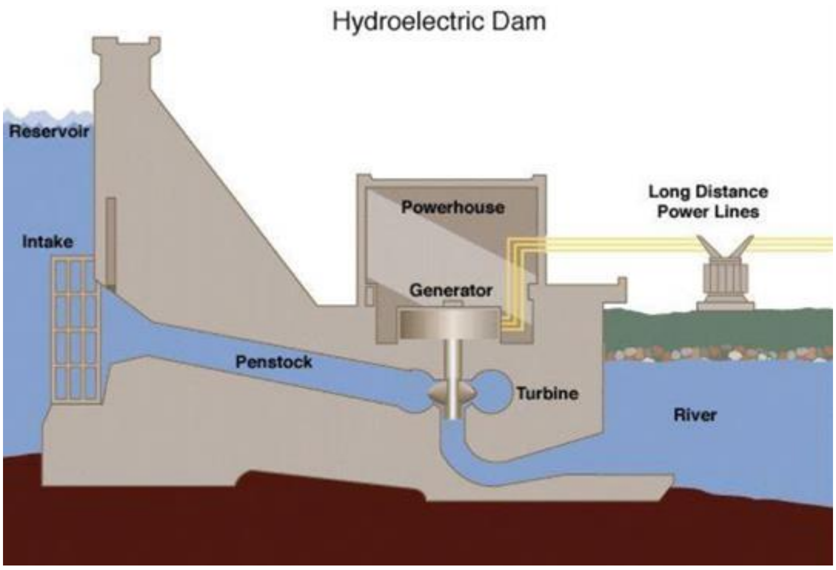

Figure 1. General structure of hydroelectric power plant

Different methods are used to optimize the usage of hydroelectric power plant such that the maximum energy is produced [21]-[25]. The turbine in the existing power plant caused the death of marine life because of the shape of the turbine. Therefore, this research proposed a prototype of vortex turbine with microcontroller and external passage such that it will reduce the death of marine life that is trapped in the flow of water in the turbine.

Based on thorough literal studies and due to the shortcomings of traditional approaches, this manuscript reports the outcomes from the development of a miniature generator that can generate electrical energy by using water flow pressure. A water vortex turbine with microcontroller and external passage is chosen as the designed structure of the system to minimize the death of the marine life. The presentation of the designed prototype is evaluated based on the different material used to develop the basin of the system and the different values of basin radius.

2. RESEARCH METHOD

The prototype development starts with eco-friendly turbine design. The existing turbine in the system is not friendly to the aquamarine life. The shape of the turbine is easily damage and the flow of water will be disturbed by the fish stuck in the turbine and reduce the effectiveness of the turbine. Thus, the spherical turbine design is chosen for this prototype. This pattern is chosen because it has greater opening and allow the small aquamarine to pass through it. Figure 2 shows the 3D design of the turbine.

The existing hydroelectrical technology affect our natural source and environment. Dammed reservoir changes the natural habitat due to the modification of river flow. In order to reduce the side effect of the designed system on the environment, gravitational vortex plant is introduced in the design of this prototype since it can create whirlpool of water and use gravity force to increase the speed of water flow. This type of plant will reduce the cost and the negative impact to the society and expands the manageability and wellbeing of the water. The gravitational vortex plant is shown in Figure 3.

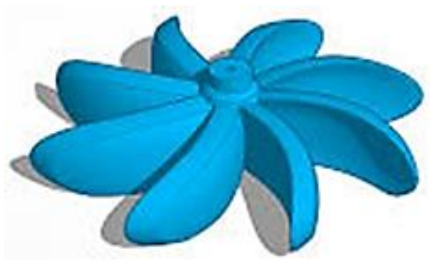

Figure 2. 3D design of spherical turbine

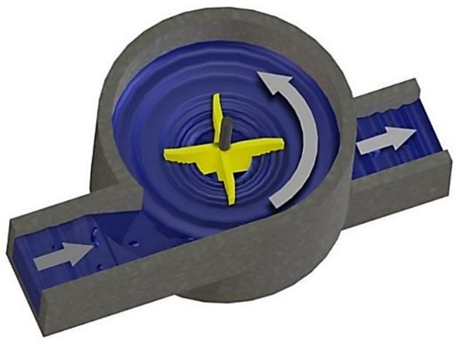

Figure 3. Gravitational vortex plant

In this prototype, the gravitational vortex power plant is designed separately from the original river flow. Therefore, it will not disturb the natural habit of the aquamarine. Besides, if the power plant break down or damage, the risk of the flood to the downstream which always happened to the current reservoir can be reduced.

In order to monitor the efficiency of the power plant such that optimum and maximum electrical energy could be generated, the designed prototype is integrated with Arduino uno and Arduino nano microcontroller. The microcontroller is completed with 5 V regulator, burner, oscillator, light emitting diode (LED) and headers to be connected to the designed system. Infrared sensor is also attached together with the circuit to detect the speed of the dc motor. Three types of material are chosen to develop the basin part; fully aluminium plate, combination of plastic and aluminium plate and combination of plastic and polyvinyl chloride (PVC) pipe. Three different models of prototype are developed by using each of these materials. The first model is illustrated in Figure 4.

The model of prototype 1 is developed by using fully aluminium plate. This material is chosen since it is easy to cut and lighter than metal plate. The dimension of the basin is 30 cm radius, 40 cm inlet length, 56 cm width and 5 cm outlet radius. The second model of prototype is designed by using combination of plastic and aluminium plate. The round shape of the basin is created by using plastic while the basin inlet is designed by using aluminium plate. The diameter of the basin is 38 cm, 26 cm inlet length, 18 cm width and the diameter of the outlet is 20 cm. The model of the second prototype is shown in Figure 5.

Figure 4. Model prototype 1

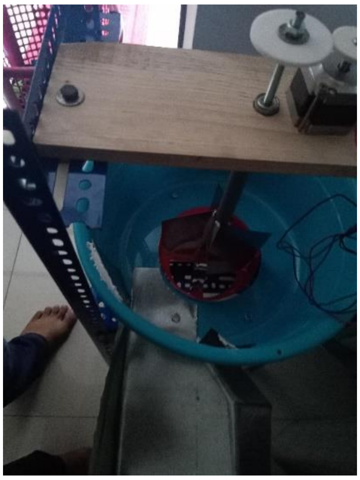

Figure 5. Model of the second prototype

The third prototype model is designed by using plastic and PVC pipe. The round shape of the basin is made of plastic and the inlet is made from PVC pipe. The diameter of the basin is 38 cm, inlet length is 30 cm, 16 cm width and the outlet radius is 10 cm. Figure 6 illustrates the third prototype model. For all these prototype models, the turbine is depicted in Figure 7.

The shaft of the turbine is fully metal covered with PVC pipe. The PVC is chosen because its dense characteristic, it is rigid and has good tensile strength compared to other plastic materials. The circuit diagram of the tachometer is built by using Arduino uno and infrared (IR) sensor is used to detect the speed of the motor. Stepper motor is chosen to be used in this design since it is flexible in application for a wider range and provides a constant holding torque without any power is supplied to the motor. The assembled circuit is illustrated in Figure 8.

Figure 6. The model of prototype 3

Figure 7. The designed turbine

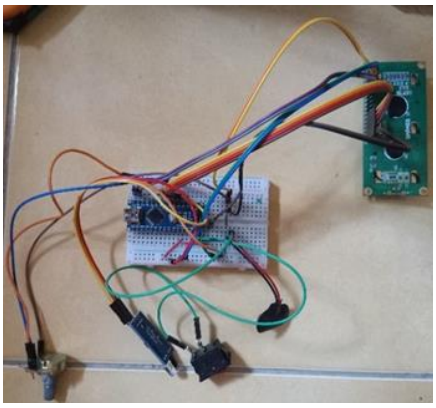

Figure 8. The assembled circuit of the controller

3. RESULTS AND ANALYSIS

Three different prototype models with different materials are developed in this research. The performance of the designed system is evaluated based on the basin shape, radius of the basin and the structure model inlet and outlet of the system. The first prototype model which is developed by using fully aluminium plate fail to tack in shape since the water flow produced high pressure on the system. Thus, the target to ensure the flow of water in vortex is not properly formed. This is because the high pressure of water flow exceeded the basin capacity.

The second prototype model is made from the combination of plastic and aluminium plate. The testing on this model shows that the basin could withstand the pressure from the water flow and form a perfect vortex. However, the inlet break after a few minutes.

In the third prototype model, the inlet of the basin is changed into PVC. The inlet of this model withstands the water pressure successfully compared to the previous two models. Table 1 list down the voltage produced by stepper motor with different radius of the basin for third prototype model.

Table 1. Outlet radius

Radius (mm)	Initial Flow Rate (L/min)	Voltage (V)
10	12.65	1.9
50	12.66	2.6
100	12.66	5.8

Based on Table 1, the 10 mm outlet radius is inefficient to create a perfect water vortex flow form as the radius is too small. Thus, the voltage produced is too small as well. The increment of outlet radius to 50mm boost the output voltage a bit higher since the radius size allows the streams line of water flow. A bigger output voltage is produced when the outlet radius is increased to 100 mm. This is because, the radius size allows the optimum water flow direction in the basin. Therefore, it shows that even though the structure and material used for the basin is expected good enough to produce high voltage, the parameters of the basin also play a significant role in order to reach the design objective.

4. CONCLUSION

This research managed to design a prototype of mini electric generator based on the principle of water flow pressure. In the methodology, a vortex design has been exploited to develop the basin part in order to reduce the bad effect on aquamarine and nature. Based on the operation of this prototype, two criterions are chosen to evaluate the performance of the designed system; type of material and radius of outlet basin. The material chosen is used to create three different structures and model of the basin. The third prototype model which is the combination of aluminium and PVC is finally chose because of its durability to the high pressure water flow. Three different values of outlet radius are tested in terms of voltage production. 50 mm outlet radius shows the highest voltage production at 5.8 V from this model compared to the other two values of radius. The outcome from this manuscript and the effectiveness of the design can be used as a benchmark to the development of actual design with commercial purposes.

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