A Comprehensive Prototype Design of Hydroelectric Power Station for Floating-Cages Energy Resources

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Abstract. This paper reported the design of a prototype of hydroelectric power station integrated in floating cages which will permanently developed in crowded of floating cages in Kampar river. The prototype was successfully created by using acrylic material with the thickness of 5mm. The examination Results shows that the prototype was working normally resulting the average voltage of 2.5 volt. Three difference wheel diameters were used for testing, and it found that the electrical current was increases as the increment of the diameter size. A designed sensor system works based on a microcontroller for detecting the water flow velocity, from the observation, the flow was 2.42 m/s. Certainly this prototype is very useful for designing the hydroelectric power station in area of floating cages at Kampar river.

Keywords: prototype, hydroelectric power station, floating cages, water wheel.

1. Introduction

The need of energy resources in various sector makes the scientists always deal with it both how to produce the greatest energy with higher efficiency. Talking about energy, this era has opened our eyes that how important it is, instead of the energy resources has become fewer especially electrical energy converted by the petroleum and gas which is obtained from the earth and also the energy yielded from the nuclear reactor system [1,2]. There are many free energy resources which have been explored and developed until now such as hydro water, wind, and the solar energy [3,4,5].

Hydro water is one of the energy resources that can be converted to the electrical power. Its high potential and kinetic energy should be profitable to drive the mechanical system of an electrical generator. A system of hydroelectric power plant has developed to convert the water mechanical energy to the electrical power by utilizing the penstock utilizing a paddle water wheel [6-10]. Various studies have been also carried out to investigate the model of the paddle water wheel work under high torque water energy storage [11].

Low efficiency of the water wheel still becomes the common problem of hydro electrical power station development. Various shapes of the cross section, the degree of positioning also has also been studied [12,13,14]. Based on the mechanical energy principle, the diameter size of the water wheel is not too important to be concerned, since it still be able to drive the mechanical system of electrical generator.

Kam par River is the longest river in Indonesia [15]. The origin of the Kampar River is in the mountainous group of Bukit Barisan in West Sumatra, and it has the estuary in Malacca Strait on the island's eastern coast. In early 1990, the Kampar river was still become the centre of society activities in Riau province from the XIII Koto Kampar district to Pulau Muda as the Kampar river estuary [16]. The potential energy of the Kampar river has been utilized by an hydroelectric power station (PLTA) Koto Panjang which operated since 1997 in Riau and West Sumatra provinces. Currently, Kampar
River has become the centre of economic system of its littoral society. Thousand floating cages were built at the Kampar river from the upstream to downstream.

This research is to design a prototype of hydroelectric power station for floating cages crowded due to the distance of electrical source is far from the crowded. The prototyping is carried out as laboratory scale and finally it will be applied to the certain floating cages in Kampar River. Some physical parameter is going to be determined.

2. Physic concept of water wheel for driving mechanical motor

Since water in the river always flows at the time from the upstream, the water load can be measured by using current meter based on the hygrometry method due to determine about the potential energy that will be used for the energy resource. The water load can be written as follow,

\[ Q = AV \]  
\[ A = \frac{1}{4} \pi D^2 \]

where  
Q : debit (m³/second)  
A : cross section area (m²)  
V : average water flow velocity (m/s)

However, the measurement of the velocity is carried out at two positions of 0.2h and 0.8h, and gives the following equation.

\[ V = \frac{v_{0.2h} + v_{0.8h}}{2} \]  

Future more, the force of water to the water wheel is important to be determined. This force is induced by the water flow velocity, and also the most important is the cross section area of the wheel. The cross section area of the water wheel hampering the water flow is proportional with the force resulted to drive generator.

\[ F = \rho AV^2 \]  

where,  
F = Floating cages force (N)  
\( \rho \) = mass density (kg/m³)  
A = water wheel area (m²)  
V = water flow velocity (m/s)

The output energy in watt yielded by the hydroelectric power station is mathematically summarized as function of the height water level (h), potential energy (\( E_p = m.g.h \)).

\[ P = \rho Qhg \]  

The output power is then used to determine the efficiency of the system.

3. Design of a prototype of hydroelectric power station

To develop a hydroelectric power station at the floating cages needs some process such as designing and prototyping. The system of hydroelectric power station is designed integrated with the floating cages as it can be seen in Figure 1. Figure 1 shows the design of floating cages which is positioned on the water surface of Kampar river. Normally, 30% of the height of floating cages enter the water. To maintain the position of floating cages, six stainless steel or plastic drum are positioned at the left and right sides of the floating cages. The design also propose the system with the information panel like volt and current information and the velocity of water flow. However, the prototype design purposed in this research is shown in Figure 2. The main material of the prototype is acrylic. The system consist of 1) water load A, 2) flowing media, 3) water wheel 4) generator, 5) water velocity sensor.
Figure 1. Design of hydroelectric power plant for floating cages at Kampar river

Figure 2. A design of prototype of hydroelectric power station for floating cages

4. Results and discussion
To create the prototype of hydroelectric power station in laboratory scale is not actually easy to be done. Dealing with the acrylic, and shaping each component as same as possible with the real design was carried out in Teaching Media laboratory, FKIP Universitas Riau. The results shows in Figure 3 demonstrating the working flow of the system. It is begun with installing the frame to supporting the system. Then flowing media are positioned at the two hole in the water load A, and the end it is terminated at the cross section of water wheel. A pipe ¾ inches is used to transfer water from load box B in to water load box A by using water pump. The type of water pump is motorized by 1X4 electrical motor. Water in box A exit at two holes and then this water passing through the flowing media before it hampered by the water wheel. It causes the rotor of the mechanical system will be rotated with angular acceleration until it yields a constant rotation speed.

The rotation speed of water flow is needed to be converted to certain rotation per minute (rpm) by using two pulleys with different diameter. Bigger pulley work in wheel rotor, and another one work in generator’s rotor. Finally, the system is working normally for condition the electrical energy displayed by a light and the avometer.
Figure 3. A prototype of hydroelectric power station for floating cages made by acrylic.

Three water wheels with different diameters have been examined at the system. Table 1 shows the resulted voltage and current for each water wheel.

| No | Water wheel diameter (cm) | Electric current (A) | Voltage (V) |
|----|--------------------------|----------------------|-------------|
| 1  | 8,5                      | 0,21                 | 2,6         |
| 2  | 11                       | 0,23                 | 2,6         |
| 3  | 13                       | 0,25                 | 2,6         |
| Rata-rata | 0,23         | 2,6                 |

Table 1 gives us important information that the generator yield difference electric current. The electric current was proportional with the increasing the water wheel diameter. Based on the relationship between current and voltage, $P = VI$, the force $F = \rho AV^2$, and the torque $\tau = r \times F$, yield the following table 2.

| No | Wheel diameter (cm) | Current (A) | Voltage (V) | Velocity (m/s) | Power (Watt) | Cross section area (m²) | Force (N) | Torque (Nm) |
|----|---------------------|-------------|-------------|----------------|--------------|-------------------------|-----------|-------------|
| 1  | 8,5                 | 0,21        | 2,6         | 2,42           | 0,546        | 4x10^4                  | 2,34      | 0,09945     |
| 2  | 11                  | 0,23        | 2,6         | 2,42           | 0,598        | 4x10^4                  | 2,34      | 0,1287      |
| 3  | 13                  | 0,25        | 2,6         | 2,42           | 0,65         | 4x10^4                  | 2,34      | 0,1521      |

The type of generator used in this study is dc motor with typical output power of 0-9 volt in 1 A. The system was successfully generate the average output power of 2.5 volt or 2500 mW. At this point, the light was normally work. The sensor which work using a microcontroller (Arduino) shows that the velocity of water flow was 2.42 m/s.
5. Conclusion
A prototype of hydroelectric power station was successfully designed in laboratory scale by using acrylic material. The prototype has been working by applying water pumping to transfer water from the final container to the initial one. It was found that the average electrical power was 2.5 volt and current of 1 A. However, the different cross section area of water wheels was examined. It yields that the resulted electric current was proportional with the increment of the wheel diameter. Finally, the water flow velocity was obtained about 2.42 m/s.

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