Performance analysis of ocean water power plant as a renewable power plant for leading regions, outermost areas, underdeveloped region

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Abstract. This research for performance analysis of ocean water power plant to get design optimization based on research scenarios. The method used is experiment, by conducting a prototype analysis of the initial calculations to be included in the modeling simulation. through research scenarios to get the most optimal prototype performance. The results showed that (1) the greater the pontoon volume used, the greater the pontoon force produced, the pontoon force was not affected by the size of the pump diameter. (2) the larger the diameter of the pump used, the greater the discharge of water produced, the water discharge is not affected by the small volume of the pontoon, (3) the magnitude of the lift system to seawater is not affected by the size of the pump diameter but the size of the pontoon volume, the greater the pontoon volume used, the greater the lift power, (4) the greater the pontoon volume used, the turbine power. The result will be even greater with the diameter of the pump, the larger the diameter of the pump used, the greater the turbine power produced. From the results of the study, it can be concluded that the optimal size uses 6 pontoons and 12-inch pump diameters. The implications of this research are that in addition to increasing the value of electrification in Leading Regions, Outermost Areas, Underdeveloped Region, it can also improve the economy of the community while helping the government to succeed the National Medium Term Development Plan

1. Introduction

68 years have been independent Indonesia, but the distribution of development has not been fully felt by all Indonesian people, one of which is access to electricity for people living in remote, coastal, lagging, outermost and foremost areas that have not been reached by the electricity network from a power plant source.

Based on the 2010 census the population of Indonesia was 237 million, up 13% from the year 2000, this increase in population resulted in greater demand for electricity [1].

In 2011 there were 3.6 million new customers spread throughout Indonesia, or an increase of 36.9% from the previous year, of which only 3.5 million could be served, the rest had to wait due to limited power supplies. Total customers were 45.9 million, up 8.15% from the previous year and connected power was 75,188.86 MVA, up 11% from the previous year [2]. This condition has caused the existing plant capacity to be unable to catch up with the high rate of growth in electricity demand, therefore it makes sense if until now the Indonesian state electricity company/PT. PLN (Persero) Indonesia has not been able to meet the target of 100% electrification [3]. Not to mention the burgeoning burden of fuel
subsidies for electricity which must be borne by the government as an effect of using diesel-fired power plants.

For this reason, a new alternative power plant is needed that is able to solve the above problems, one of the potential sources of electrical energy to become one of the alternatives in providing energy resources for remote, coastal, underdeveloped and foremost communities is the use of ocean wave energy. The advantages of this energy are its abundant availability, high energy density, unlimited potential areas, and is included in the category of environmentally friendly and renewable electricity sources [4].

The effort that can be done is to create a system of ocean wave power plants that utilize the vertical energy of waves into motion energy to pump seawater into a pressurized reservoir to rotate water turbines connected to an electric generator. This system is very useful besides increasing the value of electrification because generally the 3T region is almost 'untouched' by the electricity network as well as helping the government in succeeding the National Medium Term Development Plan (RPJMN) for 2015-2019 concerning accelerating regional development 3T (Leading, Outermost and Disadvantaged) [5]. This research is a combination of previous research conducted by Massus Subekti entitled Sea Wave Hydroelectric Power Plant (PLTA-GL) [6] and merged it with patent wave Powered Generator by Raichlen et al (Unites States patent, 4,594,853, June 17 1986) [7] and wave Motor by Mordechai Welczer et al. (Unites States Patent, 4,076,463, 28 February 1978) [8] The results of this merger resulted in a new model of marine hydroelectric power plant (PLTAL) which can convert the vertical energy of ocean waves into motion energy to pump seawater into a pressurized reservoir to rotate a water turbine connected with an electric generator.

2. Method

Marine Hydroelectric Power Plant (PLTAL) belongs to the type of offshore power plant which is a combination of patent wave Powered Generator by Raichlen et al (Unites States patent, 4,594,853, June 17 1986) [7], wave Motor by Mordechai Welczer et al. (Unites States Patent, 4,076,463, 28 February 1978) [8] and Sea Wave Hydroelectric Power Plant (PLTA-GL) [6]. The way it works is by placing a pontoon to convert the vertical energy of ocean waves into motion energy to pump seawater into a pressurized reservoir to rotate a water turbine connected to an electric generator. The can system is also applied to the fishing chart for lighting and automatic fishing net shearsers. 

![Figure 1. System design.](image-url)
2.1. Research procedure

The flow of research includes:

- Pre-Research, this stage identifies the problem based on the background of the problem to be resolved. These general problems include the need for rural communities, coastal areas, and remote areas that have not yet received electricity from the Government (PT. PLN (Persero) is given electricity and the need for tools to help solve pond water pollution problems due to pollutants from waste, households, agriculture and industry, because this research is a continuation in previous research to analyze the performance of the Ocean Wave Power Plant that has been built, so that the pre-research implementation starts from analyzing existing designs.

- Study Literature, this stage is carried out to obtain calculation data from the work of the prototype that has been made so as to become the basis for the analysis to improve the performance of the Ocean Wave Power Plant.

- Location Survey, this stage is carried out in order to get a more detailed picture of wave characteristics in several locations as well as the required water discharge requirements.

- Prototype Data Collection, at this stage data collection (prototype) and dimensions need to be done to determine the size of the prototype so that it can be simulated based on the data obtained. Data retrieval is done by measuring in detail from the design that has been made using the caliper and meter.

- Comparing Preliminary Calculations with Data Obtained from the Prototype, at this stage what is done is entering data from the initial calculation into the program and comparing it with the data obtained from the field.
Prototype simulation, after getting comparative data between planning and prototype, a simulation is carried out to determine the relationship between the system parts that are changed with system performance.

Selection of Scenarios, Selection of scenarios is carried out after obtaining relationship data for changes in prototype units in the simulation, then analyzing the modifications to the simulation to determine the appropriate prototype model scenario. These modifications include 2 units, namely:

- **Pontoon**, Pontoon is a wave power conversion tool for mechanical energy that produces a force to drive a pump. Scenario selection is determined by looking at the calculation results when adding and reducing the number of pontoons used.

- **Pump**, pump is a tool used to raise sea water to a turbine. The use of the type of pump greatly affects the water flow, pressure, resulting in the need to analyze the pump diameter used by not changing the number of pontoons.

Analysis of Scenario Selection Results, Analysis of scenario selection results in order to obtain large power requires optimal height and large discharge by using as little material as possible so that the optimization of the prototype performance has been built. Measuring the system optimization in this study includes:

- Produce high water discharge.
- Produces a higher height of falling water.
- Produces large power.
- Using fewer materials and
- Cheaper.
- Research conclusion. The conclusion is expected to produce prototype optimization data

### Table 1. Combination prototype scenario analysis.

| Scenario | Pontoon | Pump |
|----------|---------|------|
|          | Sum     | Volume | Diameter |
| 1        | 2       | 20     | 8        |
| 2        | 2       | 20     | 10       |
| 3        | 2       | 20     | 12       |
| 4        | 4       | 40     | 8        |
| 5        | 4       | 40     | 10       |
| 6        | 4       | 40     | 12       |
| 7        | 6       | 60     | 8        |
| 8        | 6       | 6      | 10       |
| 9        | 6       | 60     | 12       |

Constant, Some of the constants used in this calculation are Phi (π) 3.14; gravity 9.8 m / s2; Species of sea water (ρ-sea water) 1,030 kg / m3; and sea water / m3 weight (W-sea water) 10,094 N / m3.

Assumption, Based on the results of the survey and direct measurements in a previous study at Pelabuhan Ratu Sukabumi West Java and Yogyakarta waters and based on satellite imagery, the wave parameters used in the prototype performance analysis with wave height (h) = 1 m, wavelength 3 m and wave period (T) = 4 s.

Prototype Size, The pontoon unit uses drums with a capacity of 10 liters each; The pump unit uses 8 inch, 10 inch and 12 inch diameter pipes; piston diameter (D1) adjusts pump diameter; 3 inch input diameter (D-in); 1-inch D-out diameter; cylinder length (L-sil) 120 cm; and the step length of the piston (L-step) is 100 cm.
3. Results and discussion

3.1. Wave energy

The simulation results on the combination of changes in the number and diameter of the pump (8 inch, 10 inch and 12 inch) produce wave energy as shown in Figure 3. It shows that the amount of wave energy is strongly influenced by the size of the pontoon blade, the larger the size of the pontoon blade, the wave energy the bigger the result.

Based on archimedes law with a wave height of 1 meter, a wave period of 4 seconds, a wavelength of 3 m, and half submerged pontoons produce a buoyant force similar to 101 N sebesaar thrust when using 2 pontoons, 202 when using 4 pontoons and 404 when using 6 pontoons. This shows that the pontoon force produced is proportional to the pontoon volume used, the greater the pontoon volume used, the greater the pontoon force produced. The results also showed that the pontoon force was not affected by the size of the pump diameter.

3.2. Water discharge

The simulation results on the combination of changes in the number of pontoons and pump diameters (8 inch, 10 inch and 12 inch) produce water discharge as shown in Figure 4. It shows that the amount of water discharge is strongly influenced by the size of the pump diameter, the larger the diameter of the pump the bigger it produces.
Water discharge is defined as the amount of water transferred to the reservoir per unit time. With a step length of 100 cm and a wave period of 4 s, when using a pump with a diameter of 8 inches it produces an average discharge of 0.0081 m³/s, while when using a 10 inch pump it produces an average discharge of 0.0127 m³/s and 0.0182 m³/s when using a 12 inch diameter pump. This shows that the size of the discharge is influenced by the diameter of the pump, the larger the diameter of the pump used, the greater the discharge of water produced. The results also showed that the water discharge was not affected by the small volume of the pontoon.

3.3. Water lift

![Effect of Number of Pontoons on Water Lifting Power](image)

**Figure 5.** Graph of the effect of the number of pontoons on water lifting power.

The simulation results on the combination of changes in the number and diameter of the pump (8 inch, 10 inch and 12 inch) produce effective height which is the system's water power minus 2 meter reservoir height as shown in Figure 5. Indicates that effective height is greatly affected by the number of pontoons, the more lots of pontoons or in other words the bigger the volume of the pontoon, the greater the water lift capacity of the system produced.

Water power is defined as the ability of the pump to push sea water at a certain height in order to get potential water energy. The magnitude of the lift system to seawater is not affected by the size of the pump diameter but the size of the pontoon volume is small, the greater the pontoon volume used, the greater the lifting power produced.

3.4. Turbine power

The simulation results on the combination of the number of pontoons and pump diameters (8 inch, 10 inch and 12 inch) produce turbine power as shown in Figure 6. It shows that the turbine power is greatly influenced by the number of pontoons, the greater the pontoon volume used the greater the diameter of the pump, the greater the diameter of the pump used, the greater the turbine power produced.

The output power on the turbine is calculated based on the formula $P = g \times Q \times h \times \eta_{\text{turbine}}$, [9] with a gravity acceleration of 9.8 m/s², turbine efficiency of 0.65% and effective fall height (h) is a lift height minus 2 m. Shows that the turbine power is greatly influenced by the number of pontoons, the greater the volume of the pontoon used, the greater the turbine power produced as well as the diameter of the pump, the greater the diameter of the pump used, the greater the turbine power produced. with a water discharge of 0.0081 m³/s and turbine efficiency of 0.65%, it produces turbine power of 879 watts.
Figure 6. Graph of effect of pontoon amount and pump diameter against turbine power.

3.5. Electrical power

Figure 7. Graph of effect of pontoon amount and diameter of pumps on electric power.

The simulation results on the combination of the number of pontoons and pump diameters (8 inch, 10 inch and 12 inch) produce electrical power as shown in Figure 7. It shows that electrical power is strongly influenced by the number of pontoons and pump diameters, the greater the pontoon volume used, the power the electricity produced will be even greater. Likewise, the bigger the pump meter is used, the greater the electricity produced.

Electric power is calculated based on the Pel formula = \( P_t \times \eta_g \times \eta_tm \), with power efficiency of the generator by 87% and transmission efficiency of 98%. the electrical power produced is strongly influenced by the number of pontoons and the diameter of the pump, the greater the volume of the pontoon used, the greater the electricity produced. Likewise, the larger the pump meter is used, the greater the electricity produced.

3.6. System optimization

Table 2. System size variations.

| Number of pontoons | pump diameter | pontoons force | water discharge (M3/S) | Water Lift (m) | Turbine Power (KW) | Electrical Power (KW) |
|--------------------|--------------|----------------|------------------------|---------------|-------------------|-----------------------|
| 2                  | 8            | 101            | 0.0081                 | 19.727        | 0.987             | 0.842                 |
| 2                  | 10           | 101            | 0.0127                 | 19.727        | 1.543             | 1.315                 |
| 2                  | 12           | 101            | 0.0182                 | 19.727        | 2.221             | 1.894                 |
| 4                  | 8            | 202            | 0.0081                 | 39.455        | 2.086             | 1.779                 |
| 4                  | 10           | 202            | 0.0127                 | 39.455        | 3.259             | 2.779                 |
| 4                  | 12           | 202            | 0.0182                 | 39.455        | 4.694             | 4.002                 |
| 6                  | 8            | 303            | 0.0081                 | 59.182        | 3.185             | 2.715                 |
| 6                  | 10           | 303            | 0.0127                 | 59.182        | 4.976             | 4.243                 |
| 6                  | 12           | 303            | 0.0182                 | 59.182        | 7.166             | 6.110                 |
Based on Table 2, varying the size of the system, namely the number of pontoons (2, 4 and 6), and pump diameters between 8 inches, 10 inches and 12 inches, producing the most optimal electrical energy when using 6 pontoons with a diameter of 12 inches. 6,110 watts

4. Conclusion
The conclusions in this study are:

- The greater the pontoon volume used, the greater the pontoon force produced, the pontoon force is not affected by the size of the pump diameter
- The larger the diameter of the pump, the greater the discharge of water produced, the water discharge is not affected by the small volume of the pontoon
- The magnitude of lifting power of sea water is influenced by the volume of the pontoon, the greater the volume of the pontoon used, the greater the lifting power produced
- The greater the pontoon volume used, the greater the turbine power produced
- The larger the diameter of the pump, the greater the turbine power produced
- Optimal system size uses 6 pontoons and 12-inch pump diameter

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