Performance comparison analysis Sea Waves-Hydroelectric Power Plant (SW-HPP) with Beach Waves-Hydroelectric Power Plant (BW-HPP) as renewable energy sources and raw water for shrimp/milkfish ponds in Marunda Coast, North Jakarta

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Abstract. This study conducted a comparative analysis of system performance between Sea Waves-Hydroelectric Power Plant (SW-HPP) and Beach Waves-Hydroelectric Power Plant (BW-HPP) as a source of renewable electrical energy as the source of raw water for shrimp ponds, milkfish and salt farmers by taking research sites on the coastal coast of Marunda Cilincing, North Jakarta. Using the comparative method by comparing the parameters of pump force, water inlet speed, pump inlet pressure, water inlet velocity, pump inlet pressure, water discharge, turbine power and electric power generated. Assuming a sea wave height of 2 meters, a 4 second wave period, linear waves and turbine efficiency of 0.88. The results showed that both systems are very suitable as a source of renewable energy generation and raw water for shrimp or milkfish ponds in north Jakarta Marunda Beach. With the same system size, PLTA-GL generates more electricity than PLTA-OP. Increasing the capacity and availability of water in the PLTA-GL reservoir can be done by installing 3 pump units and 1 turbine generator unit. Increasing the power capacity of the PLTA-OP unit can be done by increasing the coverage of the trap unit.

1. Introduction

Sea Waves-Hydroelectric Power plant is a power generation system that utilizes vertical energy from ocean waves to gravitational potential energy as a Figure 1(a) [1–3], whereas beach waves-hydroelectric power plant is a power generation system that utilizes horizontal wave energy into gravitational potential energy. This gravitational potential energy besides being used as a driving force for turbine generators such as hydroelectric power plants can also be used as raw water for fish ponds and salt making which is currently polluted by pollution due to high pollutants caused by household waste such as soap and detergents, agricultural pesticides and agricultural insecticides and industrial waste that flow from upstream to river mouths and into fish ponds.

In general, Wave Power Energy Converters (WEC) are divided into 6 types, Point absorber; Oscillating Water Column; Submerge Pressure Differential; Oscillating Wave Surge Converter; Attenuator & Terminator; and Overtopping Device [4-9]. Currently there is a Point absorber type wave power plant that has been installed [4], namely:
The type of Power Buoy developed by Ocean Power Technologies Company of the United States, this type converts vertical energy up and down the wave into rotary energy through a screw mechanism,

- Sea based type was developed by the Swedish Sea based AB Company, this system utilizes the vertical waveforms of wave energy up and down to drive rotors on linear motors, while the stator parts are connected to the seabed,

- The CETO type was developed by Carnegie Wave Energy Limited Company Ireland Submerged buoys are driven by ocean waves, a driving pump that pressures seawater that is sent ashore through an underwater pipe. Once on land, high-pressure sea water is used to drive hydro-electric turbines, producing electricity.

- The type of Wave Star developed by Denmar's Wave Star Energy Company, this system uses floating pontoon energy that fluctuates due to waves to obtain acceptable water and,

- AquabuOY type developed by Finavera (Aquaenergy) Company of Canada, uses a long pump which is connected to the Pelton turbine.

Another type of Point absorber is Sea Waves-Hydroelectric Power Plant (SE-HPP), The working principle of the SE-HPP is that vertical wave energy is used to pump sea water upward with the help of the lever principle. Water is stored in a reservoir to turn a turbine producing electrical energy through a generator, as show in Figure 1(a).

One of the Oscillating Wave Surge Converter is a wave power conversion tool that utilizes the horizontal energy of ocean waves Beach Waves -Hydroelectric Power Plant (BW-HPP), the working principle of BW-HPP is that horizontal wave energy is used to raise sea water through a blades unit. Water is stored in a reservoir to turn a turbine producing electrical energy through a generator, as show in figure 1(b). In this study a comparative analysis of system performance between Sea Waves-Hydroelectric Power plant and hydroelectric power plant-beach waves as a renewable electrical energy source as a supplier of raw water for shrimp, milkfish and salt farmers ponds was taken by taking the research location on the coast of the Marunda Cilincing pond, North Jakarta.

Figure 1. (a) SW-HPP, (b) BW-HPP
2. Methods

![Research Flow Diagram]

The method used in this study is a comparative analysis by comparing the performance of the Sea Waves-Hydroelectric Power plant with the hydroelectric power plant-beach waves, with stages. The study began with a Study of Literature about the results of the SW-HPP and BW-HPP research, followed by a Location Survey to obtain an initial overview of the wave characteristics and the required water discharge requirements. The next step is determining the Size of the SW-HPP and BW-HPP System, calculating the energy conversion of the SW-HPP and BW-HPP, making the calculation simulation, testing the simulation and validating the simulation calculation that has been made. The next stage is field data collection on the coast of Marunda Cilincing, North Jakarta covering wavelength, wave characteristics, wave period, coast contour, sea water conditions, pond water conditions, area of pond area, fish / shrimp types cultivated and raw water requirements, followed by entering field data into the simulation system calculations that have been made and finally conduct analysis and conclusion. Comparative analysis includes water inlet speed, pump inlet pressure, water inlet speed, pump out pressure, water flow, turbine power and generator power.
3. Results and discussion

3.1. Result

Table 1. Constant.

| Constant                        | Score | Unit   |
|---------------------------------|-------|--------|
| Phi (π)                         | 3.14  |        |
| Gravity                         | 9.8   | m/s²   |
| Density of sea water (ρ)        | 1.030 | kg/m³  |
| Sea water weight/ m³ (W)        | 10.094| N/m³   |

Table 2. Assumption.

| Assumption                    | Score | Unit  |
|-------------------------------|-------|-------|
| Turbine efficiency            | 0.7   |       |
| Transmission efficiency       | 0.98  |       |
| Generator efficiency          | 0.87  |       |

Table 3. Sea wave dimensions.

| Dimensions                    | Score | Unit |
|--------------------------------|-------|------|
| Maximum wave height (h)       | 1     | m    |
| Wave period (T)               | 4     | s    |
| Wave Frequency (f)            | 0.25  | Hz   |
| Wavelength (λ)                | 1     | m    |
| Wave Speed (v)                | 0.25  | m    |

Table 4. System size.

| System Size                    | SW-HPP | BW-HPP | Unit  |
|--------------------------------|--------|--------|-------|
| Volume of pontoon              | 200    |        | litters |
| Number of pontoon              | 2      |        | unit   |
| Mass of pontoon                | 23     |        | kg     |
| Force of pontoon               | 2,332  |        | N      |
| Arm length 1 (L₁)              | 4      |        | m      |
| Arm length 2 (L₂)              | 2      |        | m      |
| Blade style after lever        | 4,664  |        | N      |
| Length of Blade                | 1.5    |        | m      |
| Wide of Blade                  | 1      |        | m      |
| Area of Blade                  | 1.5 m² |        |        |
| Force of Blade                 | 1,431  |        | N      |
| Blade style after trapper      | 1,431  |        | N      |
| The force received by the pump | 4,664  | 2,861  | N      |
Table 5. Force pump.

| Pump                        | SW-HPP | BW-HPP |
|-----------------------------|--------|--------|
| Diameter of Pump (D₁)       | 8      | 8      |
| Long of Pump                | 1      | 1      |
| Step length of Pump         | 0.7    | 0.7    |
| Area of Pump (A₁)           | 0.03   | 0.03   |
| Volume of Pump              | 0.02   | 0.02   |
| Incoming water speed (v₁)   | 0.35   | 0.35   |
| Incoming water discharge (Q₁)| 0.006  | 0.006  |
| Pressure of Pump (P₁)       | 143,918| 88,200 |
| Pump exit diameter (D₂)     | 2      | 2      |
| Pump output surface area (A₂)| 0.002 | 0.002 |
| Outcoming water speed (V₂)  | 5.6    | 5.6    |
| Maximum height pushes water (h-max) | 12.7 | 7.1   |
| Height-water entering the reservoir | 11.7  | 6.1    |
| Water pressure to the reservoir | 10,094| 10,094 |

Table 6. Reservoir.

| Reservoir                  | SW-HPP | BW-HPP |
|----------------------------|--------|--------|
| Capacity of Reservoir      | 1000   | 1000   |
| Discharge water into the reservoir (Q₁) | 0.0057 | 0.0057 |
| The time needed for the reservoir to be full | 176 | 176 |
| The volume of water enters in 3 minutes | 1 | 1 |
| Discharge water to the turbine (Q-t) | 0.005 | 0.005 |
| The volume of water comes out in 3 minutes | 0.9 | 0.9 |
| Reserve a reservoir in 3 minutes | 0.1 | 0.1 |

Table 7. Turbine-generator.

| Turbine Generator          | SW-HPP | BW-HPP |
|----------------------------|--------|--------|
| High-water out of the reservoir | 10.7   | 5.1    |
| Power of Turbine           | 0.36   | 0.18   |
| Power of Generator         | 0.31   | 0.15   |
| Capacity of Generator      | 0.39   | 0.19   |

3.1.1. Sea waves-hydroelectric power plant. The force produced by the pontoon is 2,332 Newton, with the mechanical advantage of the lever F₂ = 2 x F₁, the magnitude of the force applied to the pump lever is 4,665 Newton, as shown in Table 4. Table 5 shows that the magnitude of the inlet water velocity is defined by the step length of the unity pump time, because the pumping position is ½ T, the time required to pump water along the pump step is 2 seconds, thus the water velocity of entry is 0.35 m/s. With a pipe diameter of 8 inches, the pump inlet pressure is defined as the ratio of pump force to the piston surface area, hence the magnitude of the inlet pressure is 143,918 N/m². With an output pipe diameter of 2 inches, the magnitude of the outlet water velocity is defined as the ratio of the product of the piston surface area (A₁) and the inlet water velocity (V₁) to the pump outlet surface area (A₂) or V₂ = (A₁xV₁)/A₂, then the magnitude of the water velocity out of 5.6 m/s.

In Table 5, using the Bernouly equation can be determined the amount of ability of the unit in pushing water up to 12.7 meters. The amount of pump out pressure is formulated according to Bernouly's law : P₂=P₁+½ ρ (V₁²-V₂²)+ρgh₁-h₂). By setting the height of the filling pipe at 11.7 meters, the magnitude of the pump out pressure is 10,094 N/m². Meanwhile, if we increase the height of the pipe to 13 meters, then the amount of pump out pressure is (-3,391 N/m²). This shows that with the parameters set above, the maximum capacity of the pump to drain water is 12.7 meters. Table 6 shows that with a reservoir capacity of 1,000 litters, the incoming water flow 0.0057 m³/s takes 3
minutes to complete the reservoir. With water flow to the turbine of 0.005 m$^3$/s, the water used to turn the turbine is 0.9 m$^3$ or 126 liters of spare reserve per 3 minutes. Table 7 shows with an effective fall height of 10.7 meters, water flow 0.005 m$^3$/s, a constant of 9.81, turbine efficiency of 0.7, transmission efficiency of 0.98 and generator efficiency of 0.87 producing turbine power of 0.36 kW and generator power of 0.31 kW.

3.1.2. Beach Waves -Hydroelectric Power Plant. The force generated by the blade is 1,431 Newton, with 2 times the wave-trapping factor producing a force of 2,861 Newton, as shown in Table 4. Table 5 shows the magnitude of the incoming water velocity is defined by the pump length step unity of time, because the pumping position is $\frac{1}{2}$ T, then the time required to remove water along the pump step is 2 seconds, thus the water inlet velocity is 0.35 m/s. With a pipe diameter of 8 inches, the pump inlet pressure is defined as the ratio of pump force to the piston surface area, hence the magnitude of the inlet pressure is 88,200 N/m$^2$. With an output pipe diameter of 2 inches, the magnitude of the outlet water velocity is defined as the ratio of the product of the pinton surface area ($A_1$) and the inlet water velocity ($V_1$) to the pump outlet surface area ($A_2$) or $V_2 = \frac{A_1 \times V_1}{A_2}$, then the magnitude of the water velocity out of 5.6 m/s.

In Table 5, using the Bernouly equation can determine the magnitude of the unit's ability to push water upwards by 7.1 meters. The amount of pump out pressure is formulated according to Bernouly's law: $P_2=P_1+\frac{1}{2} \rho (V_1^2-V_2^2)+\rho g(h_1-h_2)$. By setting the height of the filling pipe 6.1 meters m, the magnitude of the pump out pressure is 10,094 N/m$^2$. Meanwhile, if we increase the height of the pipe to 8 meters, then the amount of pump out pressure is (-8,640 N/m$^2$). This shows that with the parameters set above, the maximum capacity of the pump to drain water is 7.1 meters.

Table 6 shows that with a reservoir capacity of 1000 liters, the incoming water flow 0.0057 m$^3$/s takes 3 minutes to complete the reservoir. With water flow to the turbine of 0.005 m$^3$/s, the water used to turn the turbine is 0.9 m$^3$ or 126 liters of spare reserve per 3 minutes. Table 7 shows with an effective fall of 5.1 meters, water flow 0.005 m$^3$/s, a constant of 9.81, turbine efficiency of 0.7, transmission efficiency of 0.98 and generator efficiency of 0.87 producing turbine power of 0.18 kW and generator power of 0.15 kW.

3.2. Discussion

Figure 3. (a) Wave energy generated, (b) Pressure of pump, (c) maximum height pushes water, (d) High-water out of the reservoir, (e) Power of turbine, (f) Power of generator.
Table 8. Comparison of SW-HPP versus BW-HPP.

| Comparison                              | SE-HPP | BW-HPP | Unit       |
|-----------------------------------------|--------|--------|------------|
| Wave energy generated                   | 4,665  | 2,861  | Newton     |
| Pressure of Pump                        | 142,918| 88,200 | N/M²       |
| Maximum height pushes water             | 12,7   | 7,1    | Meter      |
| High-water out of the reservoir         | 10,7   | 5,1    | Meter      |
| Power of Turbine                        | 0.36   | 0.18   | kW         |
| Power of Generator                      | 0.31   | 0.15   | kW         |

Comparison between results Sea Waves-Hydroelectric Power Plant and Beach Waves-Hydroelectric Power Plant show on all aspects: Wave energy generated, Pressure of Pump, Maximum height pushes water, High-water out of the reservoir, Sea Waves-Hydroelectric Power Plant produce more energy compared to Beach Waves-Hydroelectric Power Plant as shown in Figure 3. That is because at Sea Waves-Hydroelectric Power Plant can be added 2 units of pontons even more to increase its energy without the need to make a trap unit as in Beach Waves-Hydroelectric Power Plant.

4. Conclusion
The conclusions in this study are:
- The results showed that both systems are very suitable as a source of renewable energy generation and raw water for shrimp or milkfish ponds in north Jakarta Marunda Beach.
- With the same system size, PLTA-GL generates more electricity than PLTA-OP.
- Increasing the capacity and availability of water in the PLTA-GL reservoir can be done by installing 3 pump units and 1 turbine generator unit. Increasing the power capacity of the PLTA-OP unit can be done by increasing the coverage of the trap unit.

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