Study on Wave Energy into Electricity in the South Coast of Yogyakarta, Indonesia

Irhas\textsuperscript{a,}\*, Rahayu Suryaningsih\textsuperscript{a}

\textsuperscript{a} Department of Engineering Physics, Gadjah Mada University, Jl. Grafika no. 2, Yogyakarta, 55281 Indonesia

Abstract

Indonesia has some potential alternative energy source including the wave energy, caused by the temperature difference between the water surface and the sea floor. The greatest potential as a renewable energy that can be developed in the south coast of Yogyakarta derived from wave energy as a power plant. The piping installation, turbine system design, the gear systems, and the generator systems are essential instruments to maximize the conversion of wave energy into electrical energy in the wave power plant. Renewable energy can be efficiently converted into electrical energy is expected to be a solution to energy needs in Indonesia.

1. Introduction

The energy crisis predicted hit the world in 2015. Due to oil scarcity and the demand for energy are increase. It is required a breakthrough to harness energy, other than non-renewable energy. Non-renewable energy dependence, resulted difficult to harness this energy because the energy limitations of the population in the future. Despite being discussed in patents since the late 18th century \[1\] modern research into harnessing energy from waves was stimulated by the emerging oil crisis in the world\[2\]. With global attention now being drawn to climate change and the rising level of CO, the focus on generating electricity from renewable sources is once again an important area of research Information regarding to wave power can obtained since already used by many countries, including Indonesia \[3\]. There are three kinds of energy in the sea, i.e. wave energy, tidal energy and ocean thermal energy. One of the energy in the ocean that can be utilized is the wave energy. Waves on the surface of the ocean with periods of 3 to 25 sec are primarily generated by winds and fundamental feature of coastal regions of the world. Other wave motions exist on the ocean including internal waves, tides, and edge waves. Waves will apply only to surface gravity waves in the wind wave range of 3 to 25 sec \[4\]. Actually, in Indonesia, the wave is as source of considerable energy. The waves of the sea are a up and down or roll of water movement. Wave energy is generated through alternative energy movement effects of air pressure fluctuations caused by the movement of waves.
The one of area that has great potential wave to generate energy waves is the southern coast of Special Region Yogyakarta. In this study observed about the techniques of wave energy conversion into electrical energy for use as an alternative energy in Indonesia and the optimization, and the advantages used of wave power plant on the southern coast of DIY.

2. Material and method

The factors that must be considered in analyzing each project category and its associated considerations [5]. Hydraulic considerations include wind generated waves, swells, currents, tides, storm surge or wind setup, and the basic bathymetry of the area. The method which is used by literature review about: South Coast of South Coast, DIY, wave power plant elements, energy conversion technique, and make some modification in number of turbine which used in power plant. Furthermore, in this study Pascal equation for calculating the air pressure efficiency for modification of wave power plant was used:

\[
\frac{P_1}{P^{l}} = \frac{P_2}{n \pi r^2}
\]

\[
\frac{P_2}{P_1} = \pi \frac{r^2}{l^2}
\]

\[
\left( \frac{P}{A_1} \right) - \left( \frac{P}{A_2} \right)
\]

Where:
P Pressure (Pa)
A Area (m²)
n Number of cylinder
l Width of Surface (m)
p Length of Surface (m)

3. Result and discussion

3.1. Wave power plant in DIY

3.1.1 Location

The location chosen for establishing the wave power plant in Indonesia is in the South Coast area of South Coast, DIY. This area is sufficient enough to be the establishment of wave power plant. Wave power in this location is enough and consistent to utilize. Furthermore, there are 3 advantages of South Coast in South Coast, DIY, as a reason to establish the wave power plant i.e.:

- Far from the estuary of the river. River estuaries definitely bring materials sedimentation in order to cover the hole where the flow of sea water into the power plant. Sedimentation considerations include the littoral material and processes and changes in shore alignment [5].
- Steep contour easy to find is suitable areas for the implementation of wave power plant. In selecting the shape, size, and location of shore protection works, to consider effects on adjacent areas.
- Land in South Coast is made of hard material.

3.1.2 Wave power data

Wave power data in South Coast of Yogyakarta obtained from metrological, climate, and geophysics agency in Indonesia. There are changes in wave height fluctuations on the south coast for a month and one of wave power data is shown in fig. 1.
Power and height waves in Indonesia have various heights in every ocean that is shown by the color distribution in Fig. 1. Pink color on the South Coast of South Coast mean in this area has height waves that reach 2 to 2.5 meters reach the shore. The observation indicated that a row of waves with an average height of 2 - 3 meters for 9 seconds can generate a power of 39kW per meter length of the waves [7]. This result can be used by people around the beach as energy supply to fill the energy requirement in that area.

3.2. Conversion technique

Wave power plant can be used in south coast in Yogyakarta. The characteristic is required to use and get the best efficiency. Differences of flow induced pressure were used in conversion technique, to change the wave energy into electric energy due to changes of fluid wave height.
The power generator consists of two basic elements are wave energy collector and generator to turn this to electricity. First, is about wave energy collector. There are 3 ways to capture wave energy, first, the buoys technology. This tool will generate the electricity from the vertical and rotational float movement. This tool can be moored on a raft floating or moored instruments on the ocean floor. Second, Oscillating water column (OWC). This tool generates the electricity from the rise and fall of the water by a wave in a cylindrical pipe with holes. The rise and fall of the water column will result in the entry and exit of air at the top of the pipe hole and drive a turbine that is shown in fig.3.

Last, Wave Surge or Focusing Devices. This equipment commonly referred as tapered (tapered channel) or canal embed system, mounted on a structure that was built in the coastal canal to concentrate the waves, bringing it into an elevated reservoir. Water flowing out from the storage ponds is used to generate electricity by using standard hydropower technologies [3].

Wave capture technology that suitable for use in wave power plant model which established in Yogyakarta is used the oscillating water column. This tool generates electricity from the rise and fall of the water by a wave in a cylindrical pipe with holes. The rise and fall of the water column resulted in the entry and exit of air at the top of the pipe hole and drive a turbine that explained above.

The second basic component is generator to turn this to electricity. The energy collector comprises a sloping reinforced shell built into the rock face on the Shoreline with an inlet big enough to allow seawater to freely enter and leave the central chamber. As waves enter the shell chamber, the level of water rises, is compressing the air in the top of the chamber. This air is then forced
through a “blowhole” and into “Wells Turbine”. The turbine has been designed to continue turning the same way irrespective of the direction of the air flow. As water as inside to the chamber as the waves outside drawback, the air is sucked back under pressure into chamber, keep the turbine moving. The constant stream of air in both directions, created by the oscillating water column, produces enough movement in the turbine to drive a generator which converts the energy into electricity. This design is used in is lay wave power station in United Kingdom. In Yogyakarta, This design can be used due to the South Coast has same characteristic between UK coast.

3.3. The modification of wave power plant

There are some modifications to optimize wave power plant to generate the electric energy including piping installation, turbine system design, generator system, and gear system. In this paper explained about the modification of piping installation to optimize the air pressure efficiency in the pipe hole which is entered into the turbine system (fig 4).

![Fig. 4. Pipe hole in wave power plant](image)

The pipe hole in the piping installation is importance to optimize the wave power plant. It is the owner’s responsibility to select the Code Section(s) that most to a proposed piping installation. Factors to be considered by the owner include: 1) scopes of the Code Sections, 2) jurisdictional requirements, and 3) the applicability of non-B31 codes and standards. Each Code Section should be applied as a whole to a given selection of piping. For some installations, more than one Code Section may apply to different parts of the installation. The owner is also responsible for imposing requirements supplementary to those of the Code to assure safe piping for the proposed installations. This article provides guidance in the form of descriptions of the ASME B31 Code sections to assist the owner in making the best selection.

One of the importance components in piping installation is B31.1 Power Piping. It is piping typically found in electric power generating stations, in industrial and institutional plants, geothermal heating systems, and district heating and cooling systems. B31.1 has requirements for piping for steam, water, oil, gas, air and other fluids; metallic and nonmetallic piping; all pressures; temperatures greater than -29º.

Table 1. Element of air pressure efficiency (n pipe and 1 pipe).

<table>
<thead>
<tr>
<th>Element</th>
<th>n pipe</th>
<th>1 pipe</th>
</tr>
</thead>
<tbody>
<tr>
<td>p (length)</td>
<td>5.0</td>
<td>10.0</td>
</tr>
<tr>
<td>1 (width)</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>r (radius of pipe)</td>
<td>0.5</td>
<td>2.0</td>
</tr>
</tbody>
</table>

As explained before that one of the modification of wave power plant (table 3) is optimized the air pressure efficiency in the pipe hole of piping installation. This air pressure is important because it will influence the rotary of turbine system. This modification is done to remain stable turbine system so that no power fluctuation generated when there are fluctuations of unstable waves. As usual, wave power plant is used 1 pipe with 1 turbine system (2 turbines) which is in the middle of the pipe.

Table 2. Air pressure efficiency of 1 pipe.

<table>
<thead>
<tr>
<th>$P_2/P_1$</th>
<th>N</th>
<th>$1r^*/pl$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.005309649</td>
<td>1</td>
<td>1.005309649</td>
</tr>
</tbody>
</table>

If the sea waves are large, it will generate large air pressure that made fast turbine spin. Conversely, if a sea waves are small, it will generate small air pressure that made slow turbine spin. The turbines spin fluctuations should be avoided in order to have no affect for the power generated. To optimize the air pressure efficiency in pipe hole before entered to the turbine system is carried out by calculating the air pressure efficiency in the variations of amount pipe used. To calculate the air pressure efficiency is used Pascal equations.

Table 3. Air pressure efficiency n pipe.
Furthermore, by using equation [3] can be searched optimization of variations the number of pipes \( n \) to be used in wave power plant and obtained the following data.

<table>
<thead>
<tr>
<th>( P_2/P_1 )</th>
<th>( N )</th>
<th>( \Pi r^2/pl )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.63</td>
<td>10</td>
<td>0.062832</td>
</tr>
<tr>
<td>0.69</td>
<td>11</td>
<td>0.062832</td>
</tr>
<tr>
<td>0.75</td>
<td>12</td>
<td>0.062832</td>
</tr>
<tr>
<td>0.82</td>
<td>13</td>
<td>0.062832</td>
</tr>
<tr>
<td>0.88</td>
<td>14</td>
<td>0.062832</td>
</tr>
<tr>
<td>0.94</td>
<td>15</td>
<td>0.062832</td>
</tr>
<tr>
<td>1.01</td>
<td>16</td>
<td>0.062832</td>
</tr>
<tr>
<td>1.07</td>
<td>17</td>
<td>0.062832</td>
</tr>
<tr>
<td>1.13</td>
<td>18</td>
<td>0.062832</td>
</tr>
<tr>
<td>1.19</td>
<td>19</td>
<td>0.062832</td>
</tr>
<tr>
<td>1.26</td>
<td>20</td>
<td>0.062832</td>
</tr>
</tbody>
</table>

From the fig. 5 it can be seen that the air pressure efficiency of the wave power plant that uses 1 large pipe will be equal to the wave power plant that uses 17 small pipes. Small pipes can optimize the efficiency of air pressure by closing or opening the pipe hole. When the wave is large, all of the pipe will be opened for the air to flow into the turbine, whereas if the wave is small, then the pipe will only partially open so the pressure to the turbine system will remain stable.

3.4. The advantages of wave power plant

The ocean current energy usage besides environmentally friendly, energy also has large kinetic energy intensity than the other renewable energy. Due to the density of sea water that is 830 times the density of air ocean current turbines will be much smaller than the wind turbines. The other advantage is no need to design redundant power structures such as wind turbines are designed to take into account the hurricane because the physical conditions at certain depths tend to be calm and predictable [3]. Energy is the energy of the waves to be had every day, will never run out and do not cause pollution because there is no waste. In addition to the economic value that is promising there are other things that can give you an advantage in the environmental field. This energy is more environmentally friendly, does not cause noise pollution, emissions of CO2, and still be able to preserve the ocean.

3.5. The optimizes of wave power plant to the next research

The optimization can be performed using more specific data. It is intended that the condition of coastal waters are the most suitable for the use of wave power. In addition, the conversion calculation also takes into electricity with the use of a particular turbine. The optimization is done by replacing and testing the types of turbines that already exist or are still in the research stage. Expected result from this research are the use of electricity from wave power plant to community. The use of electricity to meet specific needs of the lighthouse can be used as the basis for the calculation on wave power reactor technology.
4. Conclusion

Wave energy is a potential renewable energy to be developed in Indonesia. One of the areas that have potential to convert wave energy into electrical energy is in the south coast of DIY. In this area has been established wave power plant models using an oscillating water pond technology. Furthermore, the design of the generator system is expected to develop wave energy in Indonesia will use design like a design that has use in the wave power plant in United Kingdom. Wave power plant in Indonesia has large kinetic energy intensity than the other renewable energy. The air pressure efficiency of the wave power plant uses 1 large pipe will be equal to the wave power plant that uses 17 small pipes. Small pipes can optimize the efficiency of air pressure by closing or opening the pipe hole

References