Analysis of sea wave power plant design in Bangka Island Indonesia

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Abstract. Indonesia has a vast ocean of energy resource potential to be utilized including ocean wave energy. Sea waves can be used to drive electricity generation as an alternative to replacing electricity from fossil fuels. This research was conducted to determine the potential rotation of the electric motor drive shaft in two alternative designs of sea wave power plants (PLTGL). The analysis of shaft rotation results was done by collecting sea wave data in the coast of Bangka and making a PLTGL design in the Solid Works application. Next, the sea wave data was included as a parameter of the motion study simulation. Of the two alternative designs of PLTGL, the circular type gets the highest shaft rotation, which is 29.16 rpm. Although this research ignores the factors of material strength and load resistance, this research can be continued to find out more, either in the form of electricity generated or modified mechanism design.

1. Introduction
Indonesia as an archipelago with an area of 1,904,556 km² consisting of; 17,508 islands, 5.8 million km² of ocean and 81,290 million km of beach length, the potential of ocean energy, especially ocean waves, is potential to be empowered as a new and renewable alternative primary energy especially for power generation. Hasan, et al [1] has conducted studies that explain the investigation of pattern power plants and emissions in Indonesia for the past 23 years from 1987-2009. This study shows that Indonesia's electricity sector is still very dependent on fossil fuel resources, especially diesel oil and coal as primary energy sources and this is also a major contributor to greenhouse gas emissions in the country. Several power plant designs that utilize sea wave energy have been studied [2], [3], [4]. According to the National Energy Management Plan 2005-2025 targets the use of renewable energy, one of which is wave energy, amounting to 0.2% of the national energy needs [5].

Seeing the topographic of Indonesian islands, Indonesia needs to take a role in terms of research and development of energy from the sea, in an effort to realize the use of new renewable energy. In more detail, the problem can be formulated by asking question, how to create a mechanism that can produce electricity by utilizing ocean wave energy. As a first step, the PLTGL design begins by analyzing two PLTGL mechanism designs using the Solid Works application with sea wave data in Bangka island waters.
The purpose of this research was to obtain an alternative technology design that can produce electricity that is clean, inexpensive, practical and efficient and utilizes abundant ocean wave energy. The benefit of this research is to contribute to science in the form of a mechanical design of sea wave power plants. The results of the study will also provide input to the development of research for new renewable energy alternatives that can always be developed and are considered by parties related to regional and national energy policy makers.

2. Research Methodology
The study began by observing the condition of sea wave height in the coast of Bangka, namely in Tanjung Berikat, Central Bangka Regency. At the same time, two PLTGL designs were made using a CAD application, i.e. Solid Works. The design has the principle of utilizing the motion of ocean waves to rotate the driving shaft of the electric generating motor. Up and down movements of the sea waves move the lever which rests on a fixed frame. The lever is connected by a mechanism that connects the lever with the pinion gear as part of the rack and pinion system. Alternatives are made on the mechanism, including linear and circular combinations. Furthermore, the rack and pinion system will drive the shaft and be connected to an electric generating motor. Analysis of the results will be obtained in the form of the amount of rotation at the end of the shaft that will rotate the electric generating motor.

Two PLTGL designs that have been completed then proceed with making a simulation of the movement mechanism by entering sea wave data in the motion study in the Solid Works application. Regardless of the material strength and other loads in the PLTGL design, shaft rotation can be produced by first converting the angular velocity unit to the number of rotation on the shaft. Sea wave data obtained from the Geospatial Information Agency (BIG) in Tanjung Berikat, Central Bangka Regency. Data in the form of sea wave height and sea wave were for one month period, in January 2019. There were five data to be used as parameter data in the Solid Work application, i.e. the highest value, the lowest value, and three values in between.

The predetermined data values were entered into the Solid Works application in the motion study application. The design was simulated and produced the value of the shaft rotation in the form of angular speed. Angular speed values were converted into rotations per minute. To get the radians value per second the formula was used:

\[ \text{rad/s} = \frac{\omega}{180} \]

Where \( \omega \) = angular velocity (deg / s). After knowing the angular velocity, then to find the rotation, it can be searched by the following equation:

\[ n = \frac{\omega}{2\pi} \]

Where \( n \) = rotation (rps). \( \omega \) = angular velocity (rad / s). After getting the results of rotation on the shaft in units of rotation per second (rps) then the next conversion to the unit of rpm will be obtained through the following equation:

\[ n = n(\text{rps}) \times 60 \text{ second} \]

Where \( n \) = Rotation (Rpm).

3. Result and Discussion
3.1. Sea wave data
Sea wave height data obtained from the Geospatial Information Agency in the form of average wave height data in the coast of the island of Bangka (Table 1) to enter data into Solid Works, Period data (T) must be converted to Frequency (Hz). Furthermore, data representation is needed to represent the
values that will be entered into Solid Works, i.e. The maximum, minimum, and three intermediate values (Table 2).

**Table 1.** Data on sea level and wave period at Tanjung Berikat Beach in January 2019

| Date       | Sea Waves |            |      |
|------------|-----------|------------|------|
|            | Height (m)| Period (T) |      |
| 1/1/2019   | 0.561     | 6.730      |      |
| 2/1/2019   | 0.675     | 7.060      |      |
| 3/1/2019   | 0.603     | 6.651      |      |
| 4/1/2019   | 0.584     | 6.118      |      |
| 5/1/2019   | 0.717     | 5.048      |      |
| 6/1/2019   | 0.722     | 5.288      |      |
| 7/1/2019   | 0.607     | 5.554      |      |
| 8/1/2019   | 0.471     | 6.013      |      |
| 9/1/2019   | 0.319     | 6.141      |      |
| 10/1/2019  | 0.285     | 4.457      |      |
| 11/1/2019  | 0.373     | 3.975      |      |
| 12/1/2019  | 0.327     | 5.211      |      |
| 13/1/2019  | 0.326     | 5.784      |      |
| 14/1/2019  | 0.322     | 5.017      |      |
| 15/1/2019  | 0.369     | 4.272      |      |
| 16/1/2019  | 0.388     | 5.445      |      |
| 17/1/2019  | 0.491     | 5.852      |      |
| 18/1/2019  | 0.502     | 6.314      |      |
| 19/1/2019  | 0.732     | 5.162      |      |
| 20/1/2019  | 0.836     | 5.290      |      |
| 21/1/2019  | 0.663     | 5.428      |      |
| 22/1/2019  | 0.516     | 5.512      |      |
| 23/1/2019  | 0.798     | 4.691      |      |
| 24/1/2019  | 1.110     | 5.100      |      |
| 25/1/2019  | 1.220     | 1.226      |      |
| 26/1/2019  | 1.174     | 5.182      |      |
| 27/1/2019  | 0.956     | 4.897      |      |
| 28/1/2019  | 0.770     | 4.637      |      |
| 29/1/2019  | 0.689     | 4.467      |      |
| 30/1/2019  | 0.378     | 4.895      |      |
| 31/1/2019  | 0.765     | 4.926      |      |

The data chosen to be data that will be entered into the motion study application are as follows:

**Table 2.** The data chosen for Solid Works application

| No | Wave Height (m) | Period (T) | Frequency (Hz) |
|----|-----------------|------------|----------------|
| 1  | 0.285           | 4.457      | 0.224          |
| 2  | 0.561           | 6.730      | 0.148          |
| 3  | 0.722           | 5.288      | 0.189          |
| 4  | 0.956           | 4.897      | 0.204          |
| 5  | 1.220           | 1.226      | 0.190          |
3.2. Explanation of two PLTGL design
The system in the design of a PLTGL with a linear and a circular rack gear and pinion combination system are to make use of the motion of the ocean waves that will be in contact with the buoy which will provide a linear motion that is a vertical up and down motion which is then continued by the buoy lever. The float lever is connected to the linear rack gear (Fig.1) and circular rack gear (Fig.2) so that those rack gears rotates the pinion connected to the shaft or changes the vertical motion into rotational motion. The resulting rotation on the shaft is one-way rotation thanks to the ratchet mechanism on the pinion gear. The movement of the pinion gear will give only one direction force when the buoy moves up. When the buoy is down, there will be no transfer of force between the rack and pinion gears. Next on the shaft mounted a flywheel which is useful when the pinion gear does not receive force, rotation on the shaft will not drop significantly. Next to continue the rotation on the shaft to the motor, a belt is attached. The resulting rotation is expected to be converted into electrical energy.

Figure 1. Linear Rack Gear Design
Figure 2. Circular Rack Gear Design

3.3. Simulation of two PLTGL design
To find the value of rotation per minute of the electric motor drive shaft, we need the data entered into the Solid Works application in the form of Frequency data. The output value was angular speed in degree per second. To find out rotations per minute, it was first converted into angular speed radians per second and finally converted to rotations per minute.

Figure 3. Simulation analysis procedure
For circular rack gear design, the wave height will be the same as the path length of the circular rack gear mechanism. Meanwhile for linear rack gear design, the length of the path traveled will depend on the tilt angle between the buoy and linear rack gear so that the rotation of the pinion is smaller than that of the circular rack gear.

| No | Sea Waves Height (m) | Frequency (Hz) | Linear Rack Gear Design | Circular Rack Gear Design |
|----|---------------------|---------------|-------------------------|--------------------------|
|    |                     |               | Angular Speed Deg/s (Max) | Rotation (n) (rad/s) | Rotation (n) (rpm) |
|    |                     |               | 37                      | 0,102                  | 0,980         |
| 1  | 0,285               | 0,224         | 21                      | 0,058                  | 0,556         |
|    |                     |               | 46                      | 0,127                  | 1,219         |
| 2  | 0,456               | 0,148         | 26                      | 0,972                  | 0,689         |
| 3  | 0,722               | 0,189         | 76                      | 0,211                  | 2,014         |
| 4  | 0,956               | 0,204         | 56                      | 0,155                  | 1,484         |
| 5  | 1,22                | 0,190         | 109                     | 0,302                  | 2,890         |
|    |                     |               | 93                      | 0,258                  | 2,466         |
|    |                     |               | 131                     | 0,363                  | 3,474         |
|    |                     |               | 111                     | 0,308                  | 2,944         |

4. Conclusion
Based on the analysis of sea wave power plants (PLTGL) with a combination of circular rack gear and pinion in the bonded coast, the highest rotation is 29.16 rpm at height and wave frequencies 1.22 m and 0.190 Hz respectively. The lowest rotation is 5.46 rpm at wave height of 0.285 m and frequency of 0.224 Hz. So it can be concluded with the wave data obtained at the bonded coast and taken 5 wave data with the ratio of the lowest and highest waves by analyzing the simulation, the PLTGL design mechanism can produce rotation ranging from 5.46 rpm to 29.16 rpm.

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