Simulation model of darrieus turbine using software CFD (Computating Fluid Dinamyc) in Bedono Village of Demak district

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Abstract. One area in Central Java that has the potential to develop a tidal power plant is the village Bedono, of Demak regency. In the area there are places with sea currents accelerating as sea water moves towards the mouth of the river which is then used for this study site with coordinates 6 ° 55'29.0" S 110 ° 29'11.4" E. In this study, the Darrieus type H type offshore turbine, developed by NACA (National Advisory Committee for Aeronautics), is NACA 0018 which is a special blade for marine turbine applications. Simulation using Computational Fluid Dynamics (CFD) program with the condition of research location such as sea depth, sea water velocity, gravity force and seawater period used as the variable. From the simulation results using CFD obtained the highest sea water flow velocity in Bedono village occurred at 14-16 at 2.5 m / sec and the lowest at 22-24 at 0.530 m / s. The greatest boost of simulation results was obtained at the highest current velocity of 2.5 m / s from 631,115 N and torque was 315,558 Nm.

Keywords: Water-based, Sustainable, Renewable Energy, Darrieus Type H turbine, NACA 0018, Computational Fluid Dynamics (CFD)

1. Introduction

Until now, most of the electricity needs in Indonesia are still supplied from fossil fuel power plants. Petroleum still holds the highest position of 51.66%. Natural gas occupies the second level, which is 28.57%. The rest is supplied from oil energy of 15.34% and renewable energy 4.43%. The dependence on fossil fuel energy consumption and the unused utilization of renewable energy sources is one of the weaknesses in applying the equalization of energy policies ²).

As an archipelagic country Indonesia has sustainable and renewable alternative water resources such as marine / river currents, wave energy, energy temperature difference between sea level with seafloor and tidal energy of sea water. One of the areas in Central Java that has the potential to develop sea water power plant is Bedono village, Sayung sub-district on the north coast of Demak Regency.

In the area there are places with ocean currents accelerating as sea water moves toward the mouth of the river. This situation occurs because the movement of sea water mass to areas with smaller or more volumes known as venturi effect. The location of the place is in the village of Bedono with coordinates 6 ° 55'29.0" S 110 ° 29'11.4" E, which is then used as the location for this study as shown in Figure 1.
Here are several methods used to convert tidal currents into electrical energy, among others: Floating Dam and Offshore Turbines 3). Seeing the condition of tidal currents are relatively large then using an offshore turbine to convert tidal currents into electrical energy is very appropriate Bedono villages, in addition to some advantages they have: cheaper installation costs, relatively smaller environmental impacts, and the location requirements so much easier that it can be installed in more places 1).

In this study, the Darrieus type H type offshore turbine, developed by NACA (National Advisory Committee for Aeronautics), is NACA 0018 which is a special blade for marine turbine applications. Simulation using Computational Fluid Dynamics (CFD) program 5). The NACA 0018 angle has the following specifications: Diameter 1.0 m, Chord length 0.1 m, 1.0 m turbine length, Density ratio 0.6, Number of blade 3, Type of blade Hydrofillnaca 0018. Reasons for choosing Darrieus type H turbine in simulation this is because the Darrieus turbine has many advantages including: not taking into account the direction of the flow due to its symmetry, the gravitational pressure is not able to reverse in the shape of the sheath, capable of operating at head and low speed 4).

2. Experimental Details

The working principle of the Darrieus type H turbine utilizes the speed of the water flow to rotate the blade, with a certain rotational speed, then the resultant velocity will produce a hydrodynamic force. The simulation is done by modeling some parameters of NACA 0018 blade, such as diameter, span and blade length. While the variables are sea water velocity, the dimension of the location where data is taken is the velocity of the ocean currents, which is a bridge with three supporting poles. Measurement of sea water velocity velocity is carried out every 2 hours on three sides of the bridge using current drogue. The result of measurement of sea water flow velocity as shown in table.1.

Table 1. Results of Sea Water Flow Speed Measurement

| Time       | Point 1 | Point 2 | Point 3 |
|------------|---------|---------|---------|
| 08.00 - 10.00 | 1.43    | 1.35    | 1.49    |
| 10.00 - 12.00 | 1.14    | 1.09    | 1.19    |
| 12.00 - 14.00 | 0.94    | 0.89    | 0.99    |
| 14.00 - 16.00 | 0.81    | 0.76    | 0.83    |
| 16.00 - 18.00 | 3.85    | 3.08    | 4.44    |
| 18.00 - 20.00 | 2.56    | 2.44    | 2.82    |
| 20.00 - 22.00 | 1.90    | 1.69    | 2.04    |
| 22.00 - 24.00 | 3.85    | 3.23    | 4.44    |
| 24.00 - 02.00 | 1.90    | 1.79    | 2.08    |
| 02.00 - 04.00 | 1.33    | 1.21    | 1.37    |
The result of other variable measurement is the condition of research location in Bedono village that is 5m sea water depth and the length between the 5m support pole. The variable that is assumed is gravity force of 9.8 m/s and sea water type 1025 kg/m³.

Modeling with CFD based on the above data, the first thing to do is determine the blade coordinates intended to get the edge of the blade. Point making using point command by instruction in the form of x and y coordinates, as simulation at research location in Bedono village using darrieus type H turbine blade NACA 0018 to get the description of turbine model intact. The next step is the creation of fluid domains. The size of the fluid domain is adjusted to the size to be analyzed i.e. the condition of the research location in Bedono village. Each of the parts of the fluid domain is defined for the boundary conditions (inlet, outlet, side and model) to be applied. Description of research location and location as shown in figure 2.

![Figure 2. Boundary Building For Propeller Simulation Model](image1)

To see the results of the simulation, the running process should be completed while the results are on the Post Processor as shown in Figure 3.

![Figure 3. Results on Post CFD](image2)
3. Results and Discussion

Current velocity data shows the highest sea water flow rate between 14.00-16.00 WIB of 2.5 m/s. This is due at that time the sea breeze blowing from sea to land, thus pushing the sea water and causing the highest sea water flow velocity of 2.5m/s in Bedono village. Sea velocity velocity data, condition of research location and model of turbine type Darrieus type H sudu NACA 0018 then simulated by using CFD to get thrust force that happened at turbine due to ocean currents passing through it. The magnitude of the torque is calculated by multiplying the thrust of the simulated CFD results with the turbine model radius. \( \tau = F \cdot R \) with \( \tau \) is torque (Nm), \( F \) is the simulated thrust force (N) and \( R \) is the Turbine Radius (m). From the simulation the greatest force value is obtained at the current velocity of 2.5 m/s 315,558N and occurs at 14.00-16.00 while the torque is 315,558Nm. Simulation results are presented in Table 2.

**Table 2. Results of CFD Simulation**

| Measurement Time | Current Speed | thrust  | Torque |
|------------------|---------------|---------|--------|
| (m/s)            | (Newton)      | (Nm)    |        |
| 08.00 – 10.00    | 1,407         | 205,780 | 102,890|
| 10.00 – 12.00    | 1,757         | 317,219 | 158,610|
| 12.00 – 14.00    | 2,133         | 462,713 | 231,357|
| 14.00 – 16.00    | 2,500         | 631,115 | 315,558|
| 16.00 – 18.00    | 0,540         | 32,181  | 16,091 |
| 18.00 – 20.00    | 0,770         | 63,869  | 31,935 |
| 20.00 – 22.00    | 1,070         | 120,886 | 60,443 |
| 22.00 – 24.00    | 0,530         | 31,040  | 15,520 |
| 24.00 – 02.00    | 1,043         | 115,029 | 57,515 |
| 02.00 – 04.00    | 1,537         | 244,393 | 122,197|
| 04.00 – 06.00    | 0,547         | 32,992  | 16,496 |
| 06.00 – 08.00    | 0,760         | 62,274  | 31,137 |

The simulation results show that both the highest thrust and torque values occur when the highest sea flow velocity is at 14.00-16.00. The graph between the thrust force against the velocity of sea water flow is shown in figure 5.

![Figure 4](image)

**Figure 4.** Graph Between Push Style and Sea Flow Rate

While the graph between Torque to sea water flow velocity is shown in figure 6.
4. Conclusion

From the calculation results of the largest tidal flow rate in the village Bedono occurs at 14-16 at 2.5 m/s and the lowest is at 22-24 at 0.530 m/s. The largest thrust of simulation results was obtained at the highest current velocity of 2.5 m/s of 631,115 N and the torque was 315,558 Nm. The minimum force required to rotate the turbine is 2.8865 N and its minimum torque is 1.4431 Nm.

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