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Prelimenary Modeling for Assessing Tidal Stream Energy Potential at the Alas Strait, Indonesia

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ABSTRACT
This study is on ocean current prelimenary modelling in Alas Strait, Indonesia, to be compared with the field observation data. The model maps coordinate for ocean current so that the potential energy resource can be identified. The model simulation is established with two different scenarios; the first scenario is using windspeed factor and the second without using that factor. Complementary variables such as bathymetry, water elevation, bottom friction, and eddy viscosity have the same value for both scenarios. This ocean current modelling use finite element method with flexible mesh. This method use two dimension numerical solution from the average incompressible Reynolds Navier – Stokes equation with the assumption from Boussinesq dan hydrostatic pressure. This model consists of continuity equation and momentum which closed by turbulen scheme. This study concludes the first scenario is a success and valid with the water surface elevation mean error is 4.2% and water current speed mean error is 10.7%. The second scenario is unseccesful as indicated by the water surface elevation mean error of 13.4% and the water current speed mean error of 11,7%, and also the phase and the trend of current speed is verging the field observation data.

Keywords: *ocean current energy, ocean current modelling, alas strait*

1. INTRODUCTION

Energy demands is a challenge that must be faced nowadays, mainly since the crude oil productivity which becomes the main energy supply worldwide that reaches 80% is decreased gradually. Renewable energy can be a solution for that challenge because it is more ecofriendly and almost zero pollution, for example solar, wind, geothermal, ocean energy etc [1, 2].

Ocean energy becoming one of the best resource of renewable energy in Indonesia, especially ocean current energy. Due to its huge amount of islands and straits so the ocean current movement is accelerated when passing through the straits [3].

Ocean current basically can not be exploited in the same amount continuously, because the main generator of ocean current is the tides which formed from the gravitional forces of the moon and the sun. Current speed is faster when spring tide and slower when neap tide [4]. So, it is really recommended that the current turbine can rotate in a slow current speed, as it is more efficient compared with the turbine that only rotates in fast current speed [5].

The ideal location for ocean current power plant is the area with bidirectional current, where the current speed reaches 2.0 m/s, while the ideal current speed is 2.5 m/s. The area that only has one current direction, the minimum speed should be 1.2 – 1.5 m/s. The ideal depth is not less than 15 meter and no more than 40 meter. The prospective area for the power plant development should be wide enough so that many turbines can be installed and close with the coastline so the energy transport will be easier. Cruise line and fishing area must be avoided because the risk of disturbance and accident [6].

Alas Strait is the strait that separated Lombok Island and Sumbawa Island. This strait becomes the main line between islands, industrial areas, and the living source for million inhabitants nearby. This strait has a good prospect for ocean current energy resource because the current speed relatively fast, reaches 2.0 m/s [7].

2. MATERIALS AND METHODS

This study is a research considering the data and assumptions that will result in two dimensional ocean current model to be compared with field observation data.

2.1 Data Collection

The collected data primarily is obtained from field observation to be used for model validation. Secondary data for ocean modelling comprises bathymetry, tides, and wind.

- *Bathymetry*

Bathymetry is needed for creating the model area and boundary conditions, this data are Cartesius coordinate. The *x* is *x*-axis in UTM coordinate system or latitude in Lon-Lat coordinate system, *y* is the *y*-axis in UTM coordinate system or longitude in Lon-Lat coordinat system, and *z* is the depth of the area.

This bathymetry data is obtained by digitizing the conventional bathymetry map. Digitizing itself is converting conventional map into digital numbers of coordinates and depths [8]. Figure 1 is a satellite image from Google Earth that shows the modelling area (green) and with border number 1 to 4 as mentioned in Table 1.

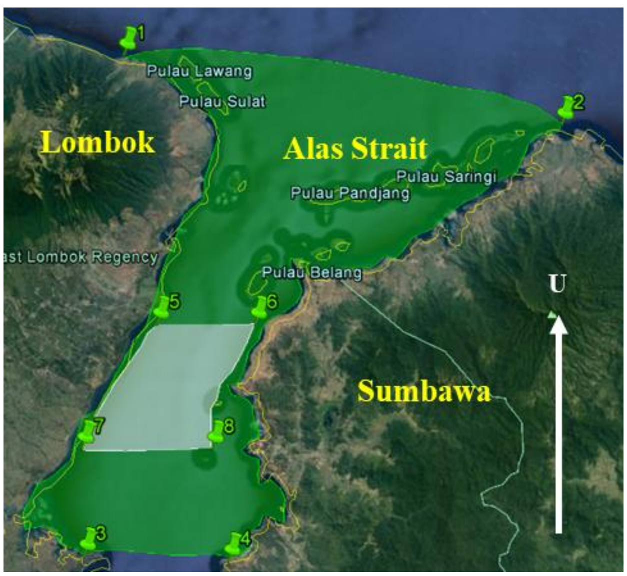

Figure 1. Modelling area (green) and ocean current energy mapping area (white)

Table 1. The Model border coordinate

Name	*x* Coordinate	*y* Coordinate
1	458119	9084817
2	515006	9075852
3	452952	9020167
4	471756	9019536
5	462493	9050081
6	475196	9050081
7	452699	9034026
8	469597	9034026

While the mapping area for ocean current energy resource is different with modelling area. Not all modelling area is mapped for ocean current energy resource [9]. This mapping area is smaller and the border is mentioned in Table 1.

The white area in Fig. 1 is the mapping area of ocean current energy resource. It is rather narrow, with small amount of sedimentation and not much hindered by islands [10]. This narrow area has bigger chance to have faster ocean current that the wide area [11].

- *Water Surface Elevation*

The type of tides in this location is a mixed tides because there are two high tides and two low tides in 24 hours, also the elevations are different in each high and low tides. In this study there are 17 tides coordinates used, 10 coordinates are in north boundary and the rest are in south boundary

- *Wind Data*

The wind data is obtained from the Badan Meteorologi Klimatologi dan Geofisika (BMKG) Selaparang, Mataram. This data is used to fill the wind driven current variable.

Figure 2 is the wind rose diagram for this study. It can be said that the dominant windspeed range from 6.7 ~ 11.1 m/s from the south, or it is called eastern monsoon that brings dry season to Indonesia.

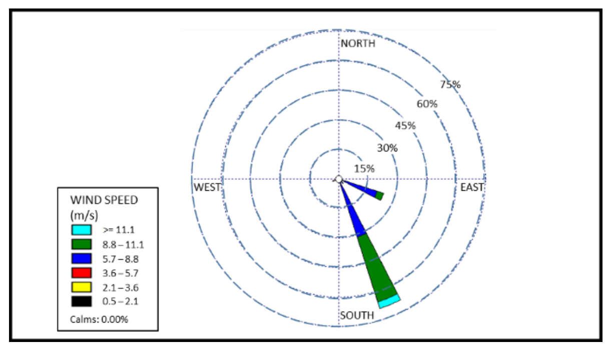

Figure 2. The wind rose diagram of the wind data

- *Field Observation Data*

It is the data obtained from direct survey on the field, which to be compared with the simulation results. The data is obtained from Balai Teknologi Survei Kelautan (BPPT Jakarta) using ADCP device in Alas Strait. The duration is from July 9 – 30th 2006. It consists of tides data and current data at *x*: 462302.2 dan *y*: 9049627 UTM coordinate, with 16 m depth below the sea surface. The current speed recorded by this device is divided into three parts namely, the surface current, the middle current, and the seabed current. Then the average current speed is taken from these three current components.

2.2 Data Processing

The bathymetry data is a digitized in coordinates of *x*- and *y*-axis and also the depth. The boundary conditions for north, south and land must be defined before the simulation can be started. The triangulation is initiated when the data is ready, it is a flexible mesh approach with three angle nets that create the simulation area. The smoother the mesh the better results will be obtained from the simulation.

Figure 4 shows the depth of the simulation which is differentiated with color codes. The brighter colors show shallow water, while the darker colors show deeper water. The grey color means outside the simulation area, islands, or land [12].

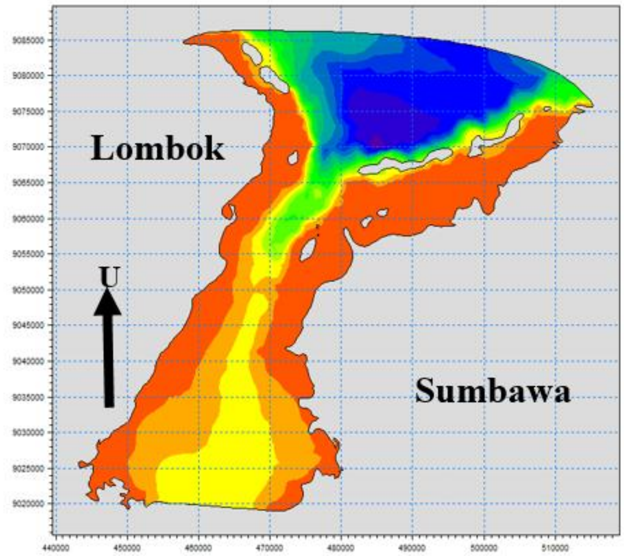

Figure 4. Interpolation at the modelling area

Tides data for the simulation is obtained from the Tide Model Generator (TMD) provided by BPPT Jakarta. It starts from June 1st 2006 at 08.00 WITA and ends in June 30th 2006 at 07.55 WITA, with 5 minutes interval and measured from mean sea level (MSL). The highest water elevation in the north border is 0.83 m and the lowest is –0.98 m, while the highest water elevation in south border is 1.38 m and the lowest is –1.41 m.

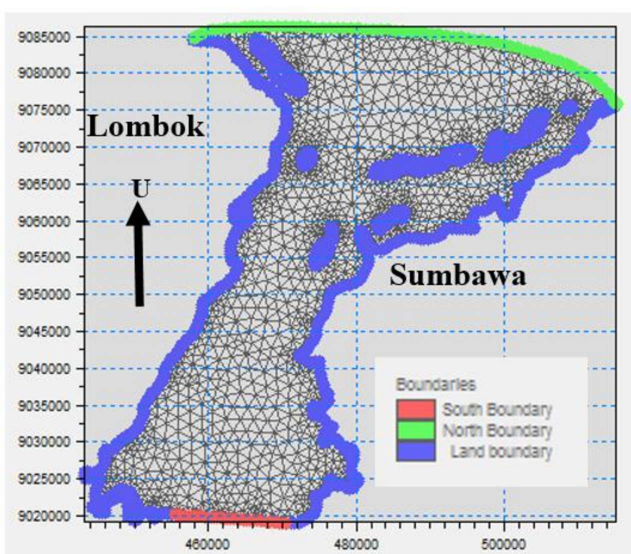

Figure 5. The boundary conditions of the model

Figure 5 shows the boundary conditions of the model. Red line is the south boundary, green line is the north boundary and the blue line is the land boundary. This boundary conditions are really important to give the model a clear definition of the area and to limit the problem of the study.

2.3 Model Validation

Model validation is performed by comparing the simulation results with the field observation data. The compared data are water surface elevation (tides) and current speed. Simulation is considered successful if the results value close to the data and with small error margin.

2.4 Mapping and Calculating the Electrical Energy

The other goal of this study is to map a coordinate in Alas Strait which has a good ocean current to be a resource of renewable energy. Grids are made of 5 intersected lines. Those intersections are taken for coordinates to be analyzed later on. The imaginary grid are made in terms for the whole time that area must be wet or cannot be dry and not a high sedimentation area [10].

These grids, as shown in Fig. 6, consists of 9 coordinates (A, B, C, D, E, F, G, H, I), and those coordinate will be analyzed one by one to get a good energy resource. The conditions for a good energy resources are as follows:

- The depth range is -15 ~ -50 meters from MSL
- Maximum current speed reaching 2.0 m/s.
- Maximum distance 3 km from the nearest coastline.
- The area is narrow because of the land, so the current will be accelerated [6,13,14].

After the best coordinate is obtained, the electrical power calculation can be initiated.

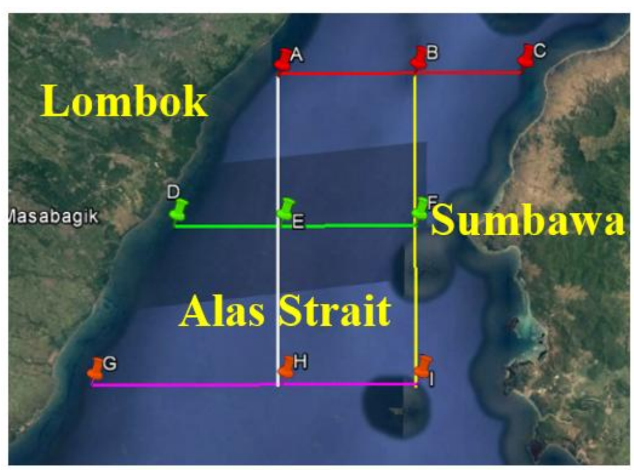

Figure 6. Ocean Current Mapping in Alas Strait

3. RESULTS AND DISCUSSIONS

3.1 Modelling Scenario

There are two scenarios conducted in this study. The first scenario ignores the wind variable and the second one involes the wind variable. Table 2 presents the variables for the two scenarios.

The current study chose variables that affect the ocean current process such as bathymetry and tides. Eddy viscosity is one of the most important variable in this simulation to solve the turbulent dynamics. The value is obtained automatically from the software with some adjustment, so does the sea bottom friction coefficient value.

Table 2. Modelling simulation scenarios

Scenario	Scenario #1	Scenario #2
Bathymetry	√	√
Tides	17 koordinat	17 koordinat
Wind	x	√
Duration	29 days	29 days
Eddy Viscosity	0,35	0,35
Sea Bottom Friction Coefficient	37 $m^{1/3}/s$	37 $m^{1/3}/s$

3.2 Modelling and Simulation

The simulation was conducted with 8000 steps x 5 minutes = 40,000 minutes, starting on June 1st, 2006 at 08.00 WITA and ending on June 29th, 2006 at 02.40 WITA. The simulation step speed is moving every 300 seconds (5 minutes), meaning the data will come out every five minutes. The interpolation result data is inputted in the modeling application and given tidal data at each northern and southern boundary according to the prescribed boundary conditions. The desired results are tidal, *u* direction, *v* direction, current velocity, and total water depth.

The duration of the simulation is determined by how much tidal data it has. In this study the initial tidal data available is approximately one month, and the field data that serves as a comparison of simulation data is for approximately twenty days

3.3 Modelling Results

- *Simulation Scenario #1*

The results from the scenario #1 are compared to the field observation data, as shown in Table 3.

Table 3 shows the result from simulation scenario 1, such as the highest and the lowest water level, mean sea level, the highest and the lowest current speed. If the value verges the observation data and the error is not so high then the simulation considered as a success.

Table 3. Comparison between simulation scenario #1 and observation

Date	Time	Obser-vation (a)	Simu-lation (b)	Deviation Percentage (b-a)/a x 100%	Anno-tation
June 14th 2016	11:00	1.10 m	1.08 m	1.8 %	Highest Tide
June 13th 2016	16:30	-1.41 m	-0.95 m	32.6 %	Lowest Tide
June 9 – 29th 2006	-	0.1 m	0.03 m	70 %	Mean Sea Level
June 15th 2006	18:30	2.19 m/s	1.33 m/s	39.2 %	Highest Current Speed
June 20th 2006	18:00	0.17 m/s	0.38 m/s	123 %	Lowest Current Speed
9 – 29 Juni 2006	-	0.97 m/s	0.93 m/s	4.1 %	Averagec urrent speed

Figure 7 is a water level elevation graph in simulation scenario #1 compared with observation data. The blue line indicates the simulation result data and the red line indicates the observation data. Based on the graph the simulation is declared successful with the difference of sea surface average (MSL) is only 0.07 m and has the same phase. Although in percentage it looks much different, that is as much as 70%, this is due to the very small values which are compared, and actually it is only two digits decimals.

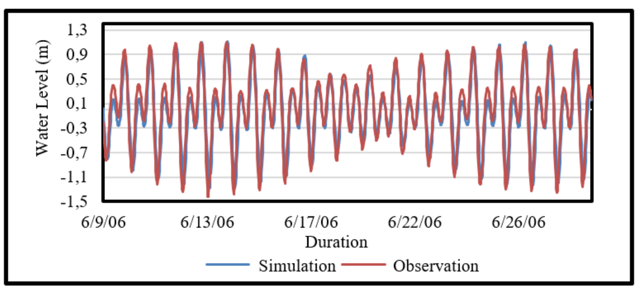

Figure 7. The validation of water level for simulation scenario #1

Figure 8 is a graph of current velocity in simulation scenario #1 compared with observation data. The blue line is the current velocity of the simulation and the red line represents the current velocity of the observed data. From the graph it is concluded that the simulation on current velocity and observation data have notably similar phase and cycle, although the velocity of the current is quite different.

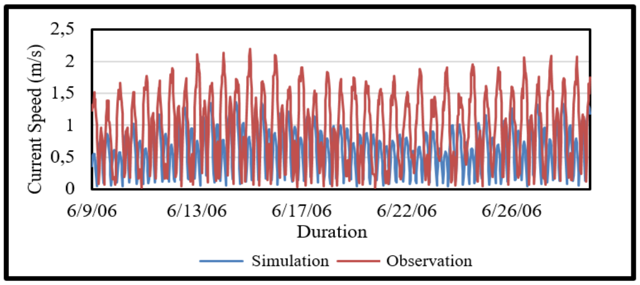

Figure 8. The validation of current speed for simulation scenario #1

It can be concluded that the current velocity of the simulation also succeeded by the difference of the average current velocity of only 0.04 m/s or the difference is only 4.1%.

- *Simulation Scenario #2*

Results of simulation with scenario #2 is compared with the observation data as depicted in Table 4. The discrepancies here are found to be larger than that in the case of scenario #1.

Table 4. Comparison between simulation scenario #2 and observation

Date	**Time**	**Obser-vation (a)**	**Simu-lation (b)**	**Deviation Percentage (b-a)/a x 100%**	**Anno-tation**
June 14th 2016	11:00	1.10 m	-0.09 m	108.1 %	Highest Tide
June 13th 2016	16:30	-1.41 m	0.61 m	143.2 %	Lowest Tide
June 9 – 29th 2006	-	0.01 m	-0.02 m	300 %	Mean Sea Level
June 15th 2006	18:30	2.19 m/s	0.49 m/s	77.6 %	Highest Current Speed
June 20th 2006	18:00	0.17 m/s	0.48 m/s	182 %	Lowest Current Speed
9 – 29 Juni 2006	-	0.97 m/s	0.54 m/s	44.3 %	Averagecurrent speed

In the simulation scenario #2, the highest tide has a value -0.09 m which is much different that is equal to 108.1% (has different phase) while the field data is 1.10 m. This indicates that there is a significant difference from the simulation #1. The lowest tide of this simulation #2 has a value of differrence of 2.02 m from the observation data or 143.2%. The average surface water elevation difference of 0.03 meters, or has a difference of 300% with the observation data. Likewise, the fastest current conditions are quite different, ie. the simulation speed is slower at 1.7 m/s. The simulateon's lowest current velocity is also different because it is faster than 0.31 m/s at the same time, and the last is the average speed. The current has a considerable margin of 0.41 m/s.

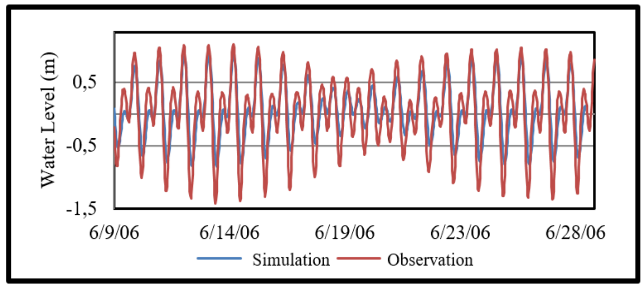

Figure 9. The validation of water level for simulation scenario #2

Figure 9 exhibits water level elevation graph in the simulation of scenario #2 and the field observation. The blue line indicates the simulated data and the red line indicates the field data. Based on the graph the simulation is declared successful with the difference of sea surface average (MSL) is only 0.05 m and has the same phase.

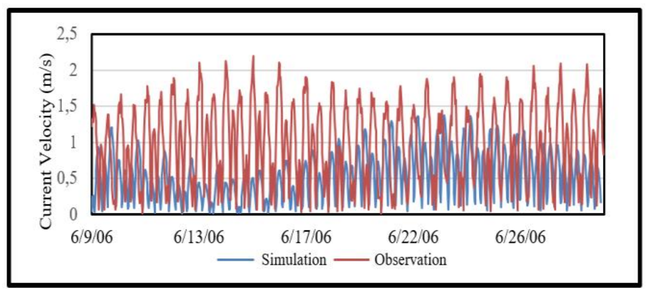

Figure 10. The validation of currents speed simulation scenario #2

Figure 10 is a graph of current velocity from simulation scenario #2 compared with the field observation. The blue line is the current velocity of the simulation and the red line represents the current velocity of the data in the field. From the graph it may be concluded that the simulation and observation data have notably differences in phase and cycle. When the field observation shows high current velocity the simulation speed is low. But when the field observation shows a low current velocity the simulation presents higher velocity. The phase and speed differences prove the simulation of scenario #2, with the addition of wind variables changes the current pattern on the strait base but does not change the existing tidal pattern. Of the two scenarios that was simulated, the scenario #1 is then selected for further use in analyzing the energy resource on the Alas Strait.

The simulation is chosen based on the error between the modeling data and observation data of both the tidal component and its current velocity components, which is formulated by:

$$Ee = \frac{Es-Eo}{Eo} \times 100\% \quad (1)$$

$$Ev = \frac{Vs-Vo}{Vo} \times 100\% \quad (2)$$

where,
Ee = sea surface elevation error
Ev = current speed error
Es = water level from modelling
Eo = water level from observation
Vs = current speed from modelling
Vo = current speed from observation

Ee and Ev are calculated for each existing data, namely from observation and simulation data, then taken its average value by the formula:

$$\text{MEe} = \frac{\sum Ee}{\sum data} \quad (3)$$

$$\text{MEv} = \frac{\sum Ev}{\sum data} \quad (4)$$

where,
MEe = mean error of water level
MEv = mean error of current speed
∑data = total data

From the formulation we get the total difference or error for each component of tidal and current velocity in each simulation as follows:

- Simulation #1
  Average error of surface elevation (*MEe*) = 4.2%
  Average current velocity error (*MEv*) = 10.7%
- Simulation #2
  Average error of surface elevation (*MEe*) = 13.4%
  Average current velocity error (*MEv*)= 11.7%

3.4 Ocean Current Energy Resource Mapping

Mapping is done by making five auxiliary lines, where some lines intersect, to be used to make a coordinate at the intersection of two lines. Coordinates at the intersections of these two lines are named as A, B, C, D, E, F, G, H and I, as shown in Fig. 6, are given in Table 5.

In general, the auxiliary line has a length of 17 km and the distance between coordinates of approximately 7 km. The line is made on condition that it does not touch the land, and never recedes until there is no water. At each coordinate the fastest and slowest current velocity data will be taken, and then the water depth and the coordinate distance from the shoreline.

Table 5. Coordinates to map the ocean current energy resource

Coor-dinate	UTM *x*	UTM *y*	Depth (m)	Current V_{min} (m/s)	Current V_{max} (m/s)	Distance from Coast-line (km)
A	462493	9050081	-10.1	0.07	1.30	2.7
B	469597	9050081	-61.0	0.03	1.80	6.7
C	475196	9050081	-19.7	0.05	1.27	1.4
D	457004	9042296	-9.0	0.03	1.10	2.4
E	462493	9042296	-45.2	0.03	1.60	7.7
F	469597	9042296	-30.2	0.10	2.38	3.0
G	452699	9034026	-18.5	0.13	1.20	1.9
H	462493	9034026	-78.6	0.09	1.89	12.3
I	469597	9034026	-42.6	0.11	2.10	4.8

These coordinates will be eliminated one by one until one of the most eligible coordinates is met, so that the F coordinates become the best potential source of ocean current energy. Of the nine coordinates which has been evaluated, the coordinate that have a good potential is F. Coordinate F has a velocity of sea currents that is good enough to reach 2.38 m/s, the depth is good for marine turbine seismic is -30.2 meters From sea level, as well as a distance of only 3 km from the coastline. This make it more accessible and less costly to transfer the energy harvested at sea to the mainland [15,16].

3.4 Calculation of Ocean Current Energy

The calculation for the potential of ocean current energy is carried out using data at coordinate F, with the slowest and the fastest current velocity data are taken. With the provision of vertical axis turbines totaling one unit and regardless of the direction and duration of the moving current, this calculation is performed. The calculation formula for the conversion of marine ocean currents into electricity [17] namely:

$$E_{k=}\frac{1}{2}\rho\ A\ v^3 \quad (5)$$

where:
ρ sea water = 1,025 kg/m^3
A (turbine cross section) = 4.0 m^2
v (minimum and maximum current velocity) = 0.1 m/s (min), 2.38 m/s (maks)

The results are:

- E_k minimum = 2.05 joule
- E_k maximum = 27,636.61 joule

The next step is to calculate the amount of electric power that can be generated from the coordinates. This is done by applying the formulation as follows:

$$P_T = \frac{1}{2}\rho\ A\ v^3 \eta_T \quad (6)$$

Where,

P_T (electrical power) in Watt
η_T (turbine efficiency / *betz factor*) = 0.3
v (minimum and maximum current velocity) = 0.1 m/s dan 2.38 m/s
A (turbine cross section) = 4.0 m^2

From the calculation 6 the results are:

- P_T minimum = 0.6 Watt
- P_T maksimal = 8,290.9 Watt

Regardless of the direction of the current, the power that can be generated from the F coordinate is in the range of at least 0.6 Watts and a maximum of 8,290.9 Watts, with the condition of one turbine installed and does not take into account the duration of the turbine. The power becomes the reference on the potential of current energy that can be harvested in the coordinate.

Figure 11 illustrates the current velocity conditions in the simulation. Black dot is the coordinate of F which is selected to be the coordinate that have a good current velocity potential as ocean current energy source. The red color indicates the highest current velocity and blue to purple color indicates the lowest current velocities. While the arrows indicate the directions of ocean current. The longer the arrow the greater the velocity of the current.

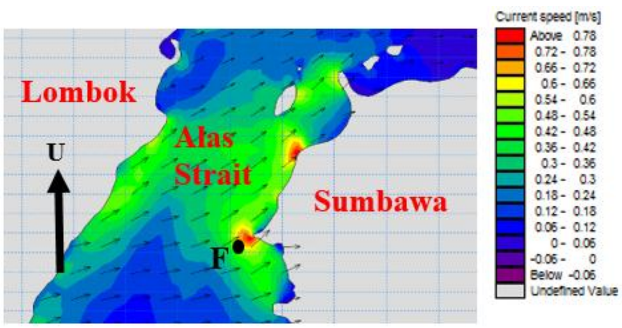

Figure 11. Coordinate F at The Simulation

6. CONCLUSIONS

The current research is focused on three main objectives namely, explaining the tidal conditions and current velocity on the Alas Strait, mapping the coordinates on the Alas Strait that have a good ocean current potential as a source of ocean currents energy, and the last is to calculate the electric power that can be exploited on the coordinates. Findings of the research are summarized as follows:

- The simulation used in this model reveals the scenario #1 has smaller error in comparison to the scenario #2. For scenario #1, sea surface elevation error is 4.2% and current velocity error is 10.71%. In this regards scenario #2 has bigger error, where the sea surface elevation error reaches 13.48% and current velocity error is 11.71%. Scenario #1 is therefore selected as the reference of tidal condition and current velocity in Alas Strait.
- Position which is potential as a source of ocean current energy is the coordinate F, that is at the coordinates of UTM *x* of 469597 and *y* of 9042296. This is in the water depth of -30.2 m from sea level, maximum speed reaches 2.38 m/s and distance from the nearest coastline is 3 km.
- The amount of energy that can be harvested from coordinate F is minimum = 0.6 Watt and maximum = 8,290.9 Watt.

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REFERENCES

1. Ayoga, T.F.: Studi potensi energi arus laut dan evaluasi kesesuaian teknologi pembangkit listrik tenaga arus laut di Selat Boleng dan Selat Patar, NTT. *Tugas* Akhir. Jurusan Teknik Kelautan, FTK – ITS, Surabaya, 2013
2. Rudkin, E.: *World Energy Council Survey of Energy Resource 2001*, 2001
3. Erwandi: *The Development of Indonesian Vertical Axis Marine Current Turbine for The Tidal Power Generation.* Indonesian Hydrodynamics Laboratory, Surabaya, 2011
4. Duxbury, A.B., Duxbury, A.C., and Sverdrup, K.A.: *Fundamentals of Oceanography*. McGraw Hill, Seattle Community College, Seattle, USA, 2002
5. Andrianto, M.W.: Studi teknis pemilihan turbin Kobold pada pembangkit listrik tenaga arus bawah laut di Selat Madura. *Tugas Akhir*, Jurusan Teknik Sistem Perkapalan, FTK – ITS, Surabaya, 2009
6. Fraenkel, P.: *Power from Marine Currents*. Marine Currents Turbines Ltd., 2002
7. Blunden, L.S., Bahaj, A.S., and Aziz, N.S.: Tidal current power for Indonesia? An initial resource estimation for the Alas Strait. *Renewable & Sustainable Energy Reviews*, Vol. 49, pp. 137-142, Elsevier, 2013
8. Khan, N.I., et al: Performance of Savonius rotor as a water current turbine. *Journal of Ocean Technology*, Vol. 4, No. 2, pp. 71-83, 2009
9. Hammar, L., and Enhberg, J.: Renewable ocean energy in the Western Indian Ocean. *Renewable & Sustainable Energy Reviews*, Vol. 16, pp. 4938-4950, Elsevier, 2012
10. Brooks, C.: *Geostrophic Current Scheme.* 2005. *Accessed from http://www4.ncsu.edu*, on November 10th 2014
11. Bowditch, N.: *The American Practical Navigator an*

Epitome of Navigation National Imaginary and Mapping Agency. Bethseda, Maryland, 1995
12. Hasan, M.H., Mahlia T.M.I., and Nur, H.: A review on energy scenario and sustainable energy in Indonesia. *Renewable & Sustainable Energy Reviews*, Vol. 16, pp. 2316-2328, 2012
13. Mukhtasor: Ocean energy in Indonesia. *Ocean Energy Workshop*, ASELI, BPPT, JICA, OEAJ and supported by ESDM and NEDO, Jakarta, 2012.
14. Mukhtasor: *Mengenal Energi Laut.* ICEES, Surabaya, 2015
15. Chen, L., and Lam, W.: A review of survivability and remedial actions of tidal current turbines. *Renewable & Sustainable Energy Reviews*, Vol. 43, pp. 891-900, Elsevier, 2015
16. Esteban, M., and Leary, D.: Current development and future prospect of offshore wind and ocean energy. *Applied Energy*, Vol. 90, pp. 128-136, Elsevier, 2011
17. Orhan, K., Mayerle, R., and Pandoe, W.A.: Assesment of energy production potential from tidal stream currents in Indonesia. *Energy Procedia*, Vol. 76, pp. 7-16, Elsevier, 2015