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CALCULATION OF POTENTIAL WIND POWER IN INDONESIA BY USING HIGH ALTITUDE WIND ENERGY METHOD

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ABSTRACT

This paper discusses the potential of wind power with high altitude wind energy (HAWE) method. Wind speed data were taken from South Bone Bay (Sulawesi) and Aru Island (Papua). Data was retrieved using satellite imagery. The data were obtained, then were simulated into wind power with different heights. Differences in altitude will increase the speed of the wind, thereby increasing average power at the turbine height from 10 meters to 400 meters increased by 2.2 times. These results show the potential use of methods HAWE in several areas in Indonesia.

Keywords: energy, high altitude, potential, stationery airborne, wind.

INTRODUCTION

Indonesia is a developing country. Electricity is one of the needs of developing countries. The Government planned to build a 35000 MW power plant [1]. The problems from this plan are the type of resources used and the equalization of electric lines.

Determination of resource type that will be used at power plants is very important, because it is not only costs but also the environmental impacts need to be considered. One ideal source of renewable is the wind. Traditionally, wind turbines were used to exploit wind energy; they require no fuel and do not produce neither toxic nor radioactive wastes [2]. The problem is a low wind speed in the surface region of Indonesia. The wind speed in Indonesia is around 8-35 km/h or 2-9.7 m/s [3]. While the wind speeds required generating electricity is 3-20 m/s [4]. The next problem is an unequal distribution of power lines and electricity network interruption.

Low wind speed can be solved by increasing the altitude. Higher altitude provides a better wind speed, so the turbine can rotate faster and provide a better power. Wind power plant usually uses a tower for supporting the generator, but build a tower is too expensive to provide a high altitude and cannot be moved to place needed. Methods that can be tried to solve high altitude and movable power plant are using high altitude wind energy (HAWE) or high altitude wind power (HAWP) [5].

Generally, HAWE or HAWP have two ways to move, which are by stationery airborne wind energy system (STAWES) and crosswind airborne wind energy system (CAWES). This paper only describes calculations with STAWES and power plants placement on balloon called on board generation (OBG). CAWES put the generator on the ground or ground-level generation (GLG) [6].

In Indonesia have the potential areas for developing wind power. Areas that have the potential can be seen in Figure-1. South Bone Bay and Aru Islands can also be seen in Figure-1 with yellow mark. South Bone Bay is located in the south of the island of Sulawesi. Aru islands located in the southern province of Papua. A good area to make wind power should have an average wind speed above 3 m/s. South Bone Bay and Aru islands have an average wind speed above 3 m/s.

CALCULATING WIND ENERGY POWER

Wind power depends on the amount of air (volume), speed of air (velocity) and mass of air (density). These three factors are flowing through certain areas (flux). Wind power can be expressed in kinetic energy:

$$K_E = \frac{1}{2} . m . v^2 \quad (1)$$

m is mass and v is speed of air. Power is kinetic energy per unit time:

$$P = \frac{1}{2} . \dot{m} . v^2 \quad (2)$$

$\dot{m}$ is mass flow rate can be calculated:

$$\dot{m} = \rho . A . v \quad (3)$$

ρ is density of air, A is rotor swept area $= \pi r^2$. So that the power equation can be calculated:

$$P = \frac{1}{2} . \rho . A . v^3 \quad (4)$$

But not all the power of the wind, P_W can be converted into power on the turbine P_T, so there is a power coefficient, C_p. Power coefficient is the ratio of extracted by turbine to the total contained in the wind resource $C_p = P_T / P_W$. Turbine power output:

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$$P_T = \frac{1}{2} . \rho . A . v^3 . C_p \quad (5)$$

The Betz law limit is maximal possible $C_p = 16/27$. The fundamental laws of conservation of mass and energy allowed no more than 59.3% of the kinetic energy of the wind to be captured.

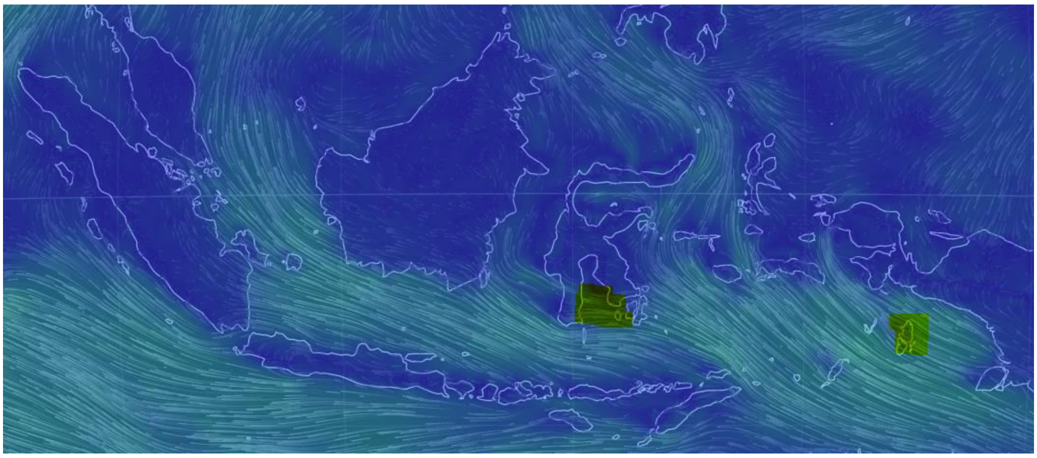

Figure-1. The wind speed in the region of Indonesia from satellite images [7].

Equation (5) can be seen that the biggest factor affecting the magnitude of the turbine power is wind speed. Wind speeds have an exponential function in influencing from the amount of power on the turbine, P_T. Indonesia has low speeds either small variation in wind speeds and rarely has a speed above 20 m/s. If the wind speed is too high or above 20 m/s, it can damage the turbine rotor. On Table-1 we can see the wind speed data in South Bone Bay using QuickScat satellite [8]. The satellite uses scatterometer to measure the sea wind speed 10 m above sea surface [9].

Wind speed data in Table-1 is still low. Speed addition can be done by adding height. The wind profile law defined by the equation between the wind speed at two different heights. Equation wind speed with height difference:

$$\frac{v}{v_0} = \left(\frac{z}{z_0}\right)^p \quad (6)$$

where, v is wind speed and z is altitude.

The exponent value is an empirically derived coefficient that varies depending on the stability of the atmosphere. For neutral stability conditions, p is approximately 1/7 or 0.143 [4]. For example, at the height 500–1000 m, mean of wind power density is about four times in every 50-150 m and 40 times at 10,000 m [10]. This point suggests that a breakthrough in wind energy generation can be realized by capturing wind power at altitudes over ground that cannot reached by wind towers [11], which is called high altitude wind energy (HAWE) or high altitude wind power (HAWP).

The method used is stationery airborne wind energy system (STAWES). The height of the turbines can be set by using a balloon filled with helium gas. The turbine will be lifted because of the buoyant effect (the density of helium gas is lighter than the density of air). Figure-2 shows one example of STAWES.

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Table-1. Wind speed of south Bone Bay in January 2008 [8].

Day	Wind speed ($m \cdot s^{-1}$)	Day	Wind speed ($m \cdot s^{-1}$)	Day	Wind speed ($m \cdot s^{-1}$)
1	6.4	12	6	23	3.4
2	5.4	13	5.8	24	3.6
3	8.2	14	4.4	25	3.4
4	8.2	15	3.8	26	3.4
5	9.4	16	3.2	27	4.2
6	7.2	17	3.8	28	4.6
7	5.6	18	3.4	29	5.2
8	4.6	19	4.2	30	5
9	4.8	20	4	31	5.4
10	5.6	21	4.2		
11	5.4	22	3.8		

Calculations and simulations with the balloon model will make it easier to get potential wind power in Indonesia. In addition the use of a balloon can be combined with solar system [13], where in Indonesia also has potential in the use of solar system. The balloon can also be used to lift the telecommunication equipment, so that not only produce electricity but also for internet and telephone connection.

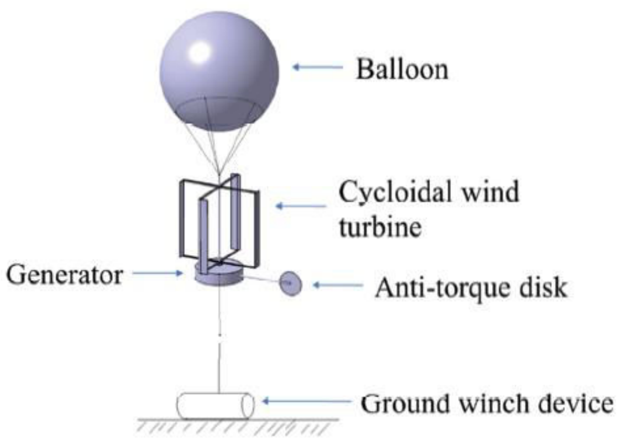

Figure-2. High altitude cycloidal wind turbine [12].

HAWE system in Indonesia is expected to solve the problem of electrical energy equitable distribution. Besides, areas of natural disasters can get power supply soon because this system I movable. Figure-3 shows HAWE Altaeros Energies transported by truck.

Figure-3. Altaeros energies transported by truck [14].

SIMULATION RESULT

The result obtained from the simulation is the wind speed data used as input of wind power. Wind speed data taken from Table-1 and Figure-1.

From the results of satellite imagery, it can be seen that southern part of Indonesia has the fastest wind approaching 10 m/s. The region is narrowed in the province of Papua, especially on the islands of Aru. The average speed of the wind on the Aru Islands is around 6-8 m/s. The data obtained in the Aru islands through satellite imagery. In the next research, it is needs to be measured on the site directly.

The data obtained in Table-1 will be inputted to the simulation turbine which has a maximum power of 4 kW. The simulation can be obtained from equation (5). Operate at minimum speed wind 3 m /s and a maximum speed of 20 m/s. The turbine blades are considered ideal by $C_p = 0.593$ and the diameter of the blade are 4 m.

The power generated in South Bone Bay at a height of 10 meters can be seen in Figure-4. From Figure-4, it can be seen the maximum power generated

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approximately 2.7 kW, whereas the maximum power of the generator is 4 kW. Low wind speeds causing the power generator was not optimal.

Power can be increased by adding the height of the turbine. From the results obtained from Figure-4, subsequent testing by adding the altitude of the simulation. The addition of altitude can be done by inserting equation (6) in the simulation. Wind speed increases will add power to the generator. Figure-5 power can be generated at an altitude of 400 meters.

The average power in the region of South Bone Bay at a height of 10 m is estimated at about 1240 W. At an altitude of 400 meters average power increased to 3262 W. Aru islands in the area at a height of 10 m average power estimated 2024 W. At an altitude of 400 meters estimated average power is 3548 W.

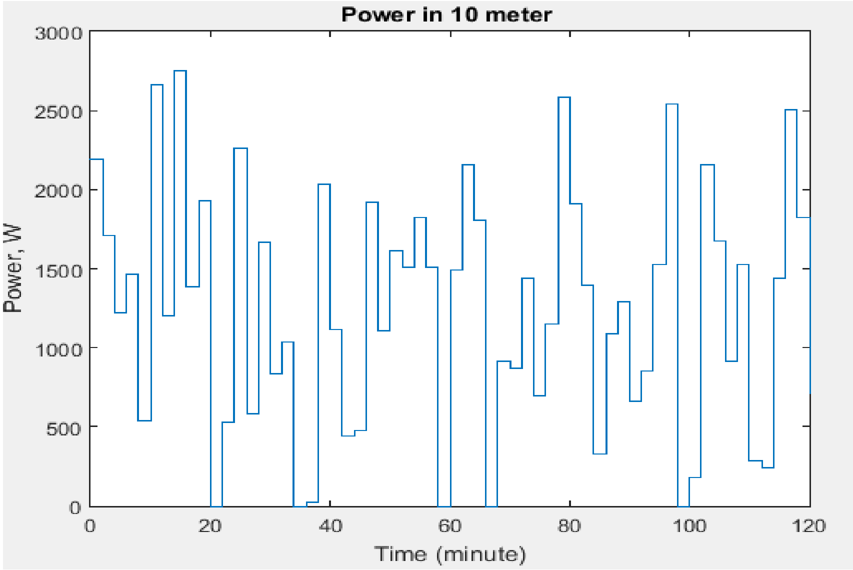

Figure-4. The power generated at an altitude of 10 meters in South Bone Bay.

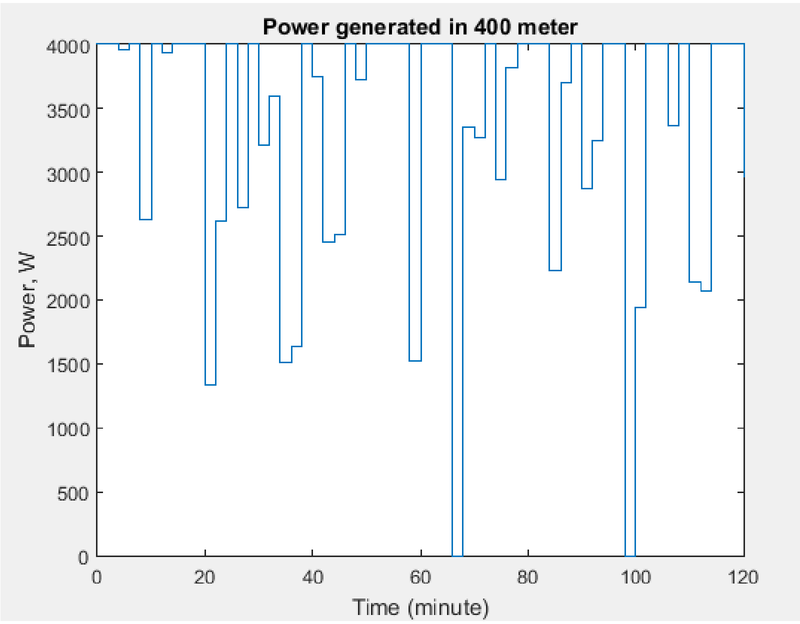

Figure-5. The power generated at an altitude of 400 meters in the South Bone Bay.

The increase in average power at different heights large enough, but the problem is the wind speed is always changing lead to an unstable power. Therefore wind power generator is used as backup or can be combined with other renewable power source. There are some other renewable power source is ocean currents, geothermal and solar cell.

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CONCLUSIONS

This research shows the potential for developing high-altitude wind energy (HAWE) in Indonesia. Prediction results showed that gaining altitude can add the average power. The maximum power of generator is 4 kW. At a height of 10 meters is very difficult to produce maximum power this happens because the wind speed is not capable of reaching 10 m/s. While at an altitude of 400 meter wind speeds many times can exceed a speed of 10 m/s. So the average power increases approximately 2.2 times from a height of 10 meters to 400 meters.

Wind speed data are taken from satellite imagery, so it is necessary surveys and field studies for a more valid data. In addition only in certain regions in Indonesia wind speeds approaching 10 m/s. Expectations on subsequent research was to survey the wind speed directly with different heights and create a prototype HAWE with buoyant airborne turbine (BAT) or crosswind airborne wind energy system (CAWES).

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