Simulation of Vertical Axis Wind Turbine (VAWT) using Turbine Blades NACA 4412 Type

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***Abstract* - Wind energy potential in Indonesia is more than 90 GB and the production of electic energy using wind has not been explored optimally. The main problem is that optimal wind energy utilization has not been explored yet while demand for electric energy is increasing faster. The objective of this research is to analyze the effect of wind speed variation on the power generated by Vertical Axis Wind Turbine (VAWT) using NACA 4412. VAWT uses 4 unit turbine blades and the variation wind speed is 4.5 to 5.2 m/second. The research variables are variation of wind speed and variation of turbine blades, and the electric power is generated by VAWT. In this simulation research we apply quantitative methods to experimental design using one way classification and data simulation. The findings of this research reveals that the faster the wind speed and the higher number of turbine blades, the higher power is generated. The null hypothesis is rejected, which means that there is a difference between variation of wind speed and the electric power generated by VAWT.**

Keywords - VAWT, Simulation, wind energy, wind speed, strategic, turbine blades.

I. INTRODUCTION

National (Indonesian) energy consumption is increasing very rapidly, especially energy consumption for industry, transportation, commercial buildings and household sectors (see Table I), because of the population growth, economic growth and energy consumption patterns itself is constantly increasing.

TABLE 1. SHARE OF FINAL ENERGY CONSUMPTION BY SECTOR [%]

Year	Industry	Household	Commercial	Transportation	Other
2010	41.09	13.14	4.79	36.56	4.42
2011	42.91	11.50	4.47	36.01	4.05
2012	42.85	11.58	4.59	37.61	3.36
2013	42.12	11.56	4.25	38.80	3.26

Source: [8,9,10].

The gap between the fuel or energy supply and demand is wider, it means the government should import the fuel or crude oil from other countries more than 300.000 bpd in 2017 and increasing the fuel subsidymore than USD 2 billion [2,6]. The decreasing of the deposit/stock of the fossil fuel, the increasing price of the crude oil, the increasing the imported crude oil, and the increasing the need for shifting the alternative energy or renewable energy. The government tried to generate or to shift non-renewable energy to renewable energy. Renewable energy is energy generated from natural resources such as sunlight, wind, rain, tides and geothermal - which are renewable (naturally replenished). One of the alternative energy and clean energy is wind energy. Horizontal axis wind turbines have already installed in Sidrap – South of Sulawesi with the capacity about 75 MW.

The contribution or share of the increasing air pollution come from an exhaust gas or the emission of the exhaust gas from the public transportation and private cars, commercial buildings, industries, and the households, see Table 1, source: Financial ministry (Sri Mulyani, 19 January 2017) [6].

Sri Mulayani (25 January 2017) [6] stated that the Indonesian government try to shift the ministries budget allocation, e.g. The decreasing energy subsidy in the year of 2014 is Rp. 350.5 trillion become Rp. 77.3 trillion (Fig. 1 and 2).

Research Objectives: The objective of this research is to analyze the effect of the wind speed variation to the power generated by Vertical Axis Wind Turbine (VAWT) using NACA 4412

II. LITERATURE REVIEW

Airfoil is a structure with curved surfaces designed to give the most favorable ratio of lift to drag in flight, used as the basic form of the wings, fins, and horizontal stabilizer of most aircraft also airfoil (Figure 3, 4 and 5).

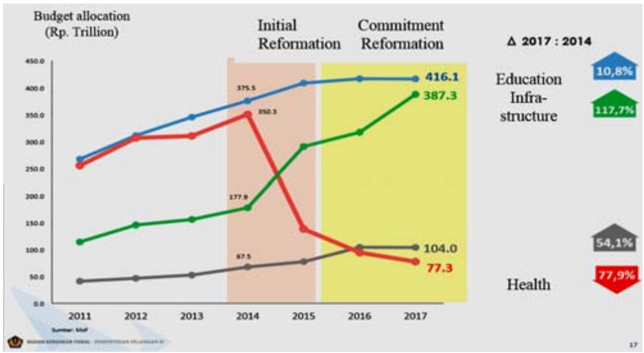
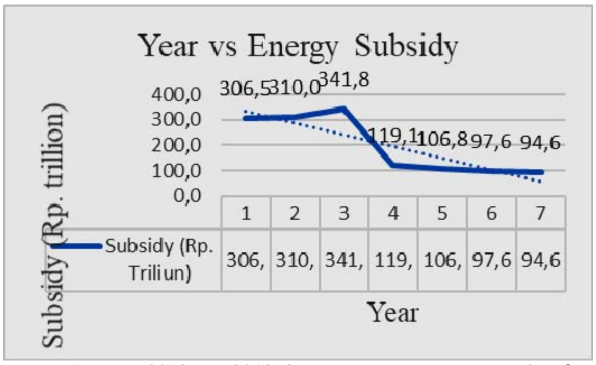


Fig. 1. Shifting the energy strategy.



NB; Year 1 = Year 2012; 7 = 2018. Source: Kompas newspaper, 25 of May 2018

Fig. 2. The decreasing energy subsidy forecasting.

A. NACA Codification

Figure 3 shows the codification of the NACA type [10].

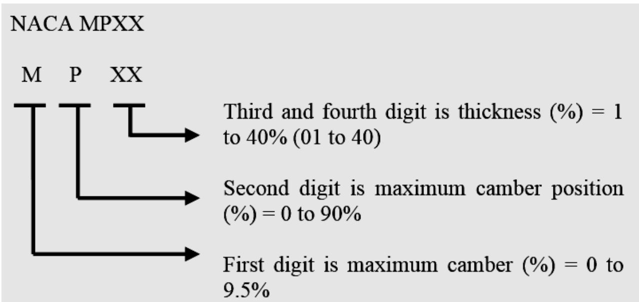


Fig. 3. NACA MPXX Codification.

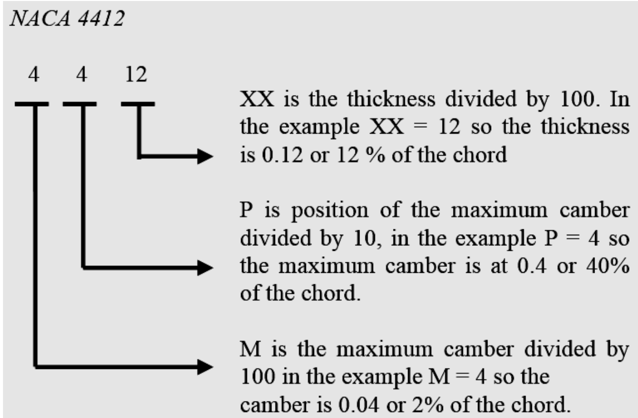


Fig. 4. NACA 4412 specification

B. Airfoil Nomenclature

Fig. 5 shows the description or the airfoil nomenclature.

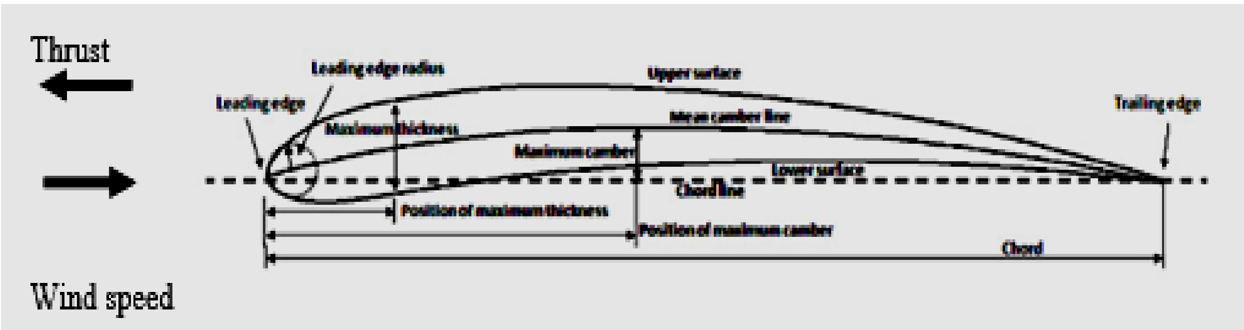


Fig. 5. Airfoil Nomenclature [2, 10]

C. Turbine Blades

Airfoil shape has an influence on the flow characteristics that passing through because of the radius of the leading edge of the airfoil, maximum chamber and maximum thickness position of the airfoil. The maximum thickness position of the airfoil will also affect the other variables, such as the location of the point of minimum pressure and generated pressure distribution. The position of the minimum pressure point should be as far back towards the trailing edge to ensure the transition from laminar flow to turbulent emergence as slowly as possible so as to reduce friction drag on the profile (Figure 5 and 6).

An airfoil-shaped body moved through a fluid produces an aerodynamic force. The component of this force perpendicular to the direction of motion is called lift (L). The component parallel to the direction of motion is called drag (D). The component of this force resultsnt of L and D is resultante (R).

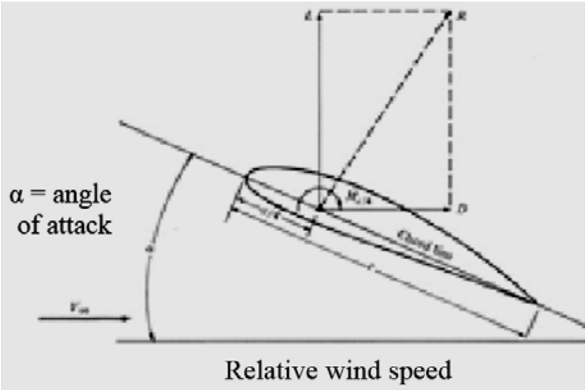


Fig. 6. Lift, Drag, and Resultante.

Fig. 7. The Microcontroller, wind tunnel and VAWT

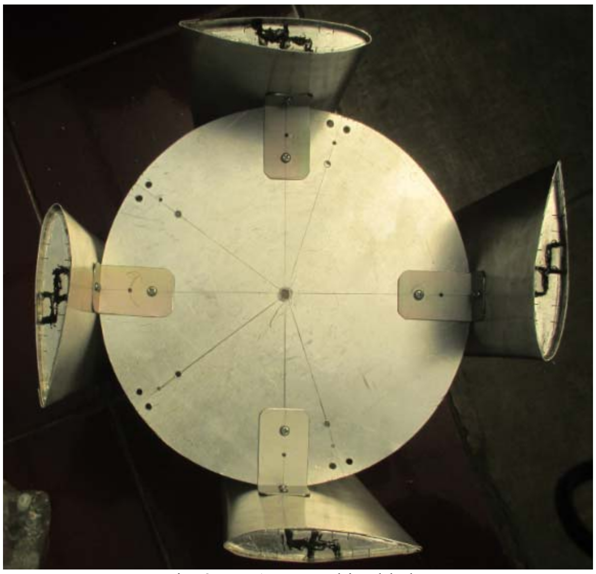


Fig. 8-a. VAWT Turbine blades

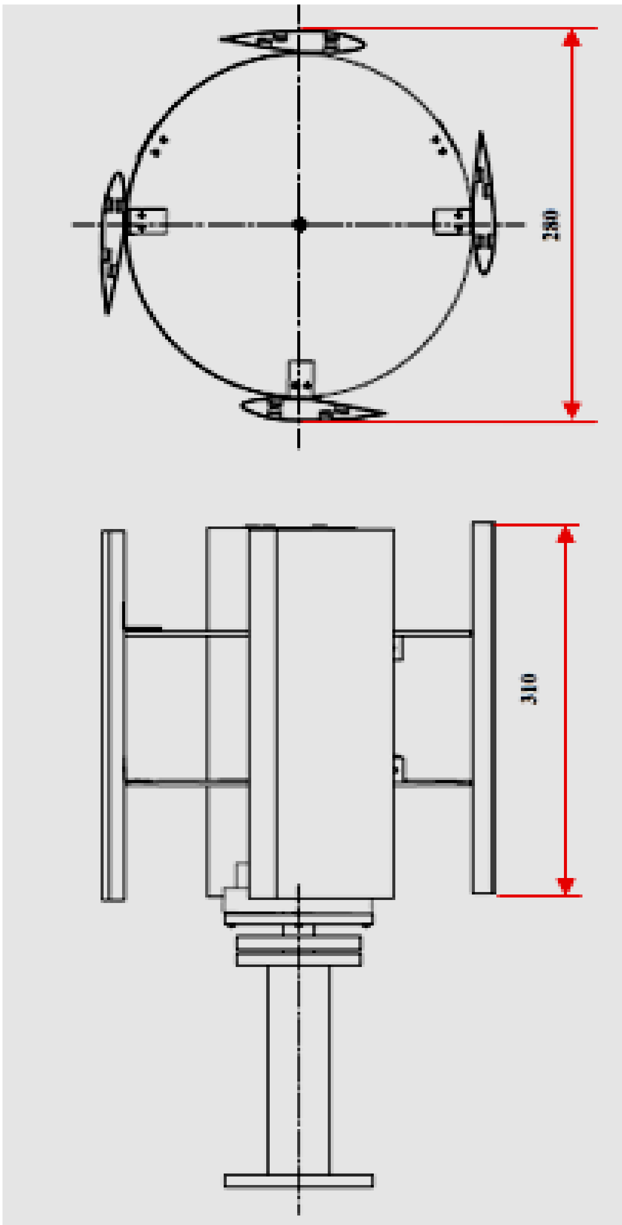


Fig. 8-b. Technical drawing of VAWT

III. RESEARCH METHOD

The research variables are the wind speed, as independent variables, and the power generated by Vertical Axis Wind Turbine (VAWT) using NACA 4412 as dependent variable.

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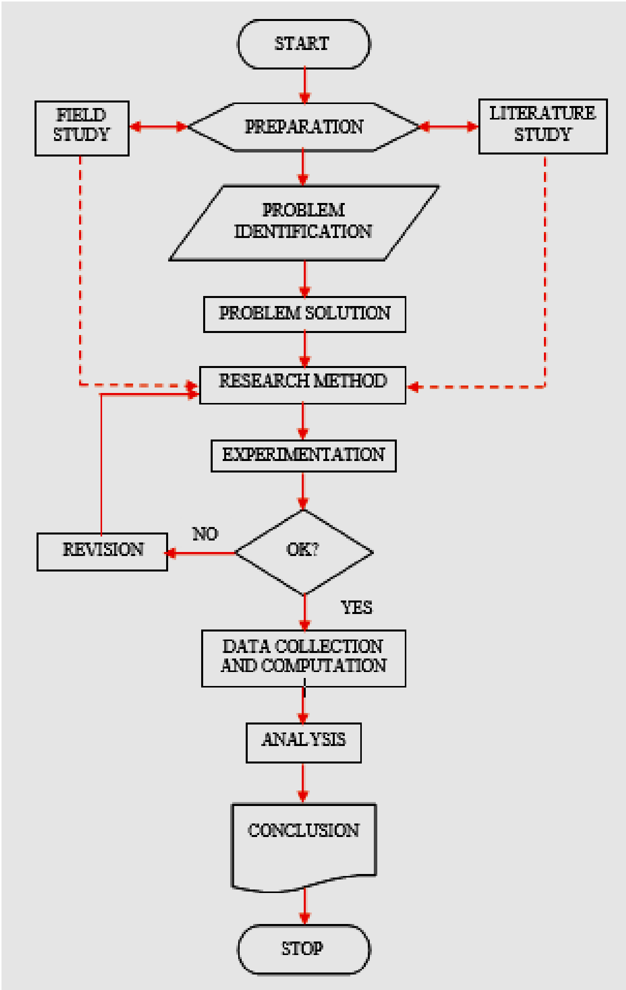


Fig. 9. Research Flow Chart

A. The Mathematical Model

The mathematical model [1, 7] is

$$Y_{ijk} = \mu + WS_i + \varepsilon_{k(ij)}. \qquad (1)$$

This research applies quantitative approach using factorial experiments. The data of wind speed (WS) vary from 4.5 m/s to 5.2 m/s. The number turbine blades is 4 unit.

B. Research Flow Chart

Figure 9 shows the research flowchart.

C. Tests of Hypotheses

The null hypotheses are accepted if the means of the variables data are not different significantly at the level 5% and the alternative hypotheses are rejected if the means of the variables are different significantly at the level 5%.

The accumulation of data wind speed can be measured by using digital anemometer, whereas the power is a multi-tester (W=VxA or volt times ampere) and microcontroller.

IV. RESULT AND ANALYSIS

A. Experimental Design

Table II shows the result of the experimentation data are the wind speed variation between 4.5 m/s to 5.2 m/s and the replication is 6 data every cell.

TABLE II. DATA WIND SPEED (M/S) AND POWER WATT

Replication	Wind speed [m/s]				
	4,5	4,7	5	5,1	5,2
1	7,108	7,372	14,042	21,556	23,1
2	6,955	7,51	14,18	21,46	23,3
3	6,933	7,328	13,9	21,134	22,8
4	7,02	7,465	13,45	20,62	23,66
5	6,844	7,234	13,9	21,04	23,972
6	6,89	7,191	14,46	21,25	23,972

After computation, we have the analysis of variance (see Table III).

TABLE III. ANALYSIS OF VARIANCE

Source of variation	df	Sum of squares	Mean square	Fratio	Ftable
Treatments	4	1399,276479	349,8191199	3635,9027	5,77
Error	25	2,405311333	0,096212453		
Total	29	1401,681791			

Source: Irwin Miller, 1985:332-341 [1,7].

Table III shows the F ratio exceed F table (see Table III) or 3.635,9027 > 5.77, it means the null hypothesis is rejected or there is a different significantly at 5%.

Tests on means after experimentation using Newman-Keuls range test (Charles R Hicks, 1983:51) [1]. Figure 10 is the result of the test, it sees that Power5 differs significantly from $Power_4$, $Power_3$, $Power_2$, and $Power_1$, where any means underscored by are not the same line are significantly different.

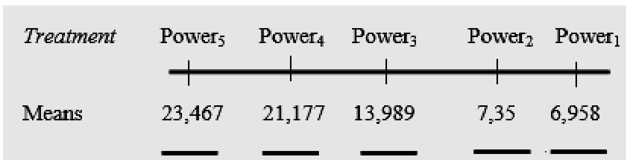
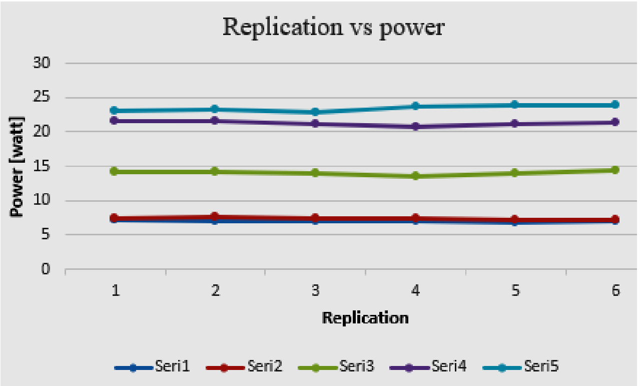


Fig. 10 Newman-Keuls test means



NB: Seri1 = Power 5; Seri 2 = Power 4 and so on.

Fig. 11. Replication vs Power and wind speed

Figure 11 show us the maximum power generated by VAWT is 23,972 watt, the wind speed is 5.2 m/s using 4 unit blades (see Table 2 Figure 4) and the minimum power generated by VAWT is 6.844 watt, the wind speed is 4.5 m/s and using 4 unit blades.

B. Strategy Development

Table 4 shows the scenario and the parameters of the strategy development uses turbine blades, wind speed and power generated by VAWT. The maximum power generated by VAWT uses 4 unit of turbine blades, the wind speed is 5.2 m/s, and the power generated by VAWT is 23.792 watt.

TABLE 4. THE STRATEGY DEVELOPMENT

No	Strategy	Alternative
1	Scenario 1	The maximum power generated by VAWT uses 4 unit of turbine blades, the wind speed is 5.2 m/s, and the power generated by VAWT is 23.792 watt.
2	Scenario 2	The second maximum power generated by VAWT uses 4 unit of turbine blades, the wind speed is 5.1 m/s, and the power generated by VAWT is 21.556 watt.
3	Scenario 3	The third maximum power generated by VAWT uses 4 unit of turbine blades, the wind speed is 5.0 m/s, and the power generated by VAWT is 14.46 watt.
4	Scenario 4	The fourth maximum power generated by VAWT uses 4 unit of turbine blades, the wind speed is 4.7 m/s, and the power generated by VAWT is 7.372 watt.
5	Scenario 5	The minimum power generated by VAWT uses 4 unit of turbine blades, the wind speed is 4.5 m/s, and the power generated by VAWT is 7.108 watt.

V. CONCLUSION

The F ratio exceed F table (see Table 3) or 3.635,9027 > 5.77, it means the null hypothesis is rejected or there is an effect between average wind speed to the power generated by VAWT significantly at 5%.

The strategy for choosing the power is the maximum power generated by VAWT uses 4 unit of turbine blades, the wind speed is 5.2 m/s, and the power generated by VAWT is 23.792 watt.

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