International Journal of Engineering & Technology, 7 (1.2) (2018) 246-250

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

The strategy of simulation effects of wind speed, variation of turbine blades and it's interaction to power generated by vertical axis wind turbine using NACA 2412

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Abstract

The objective of this paper is to simulate the effects upon the wind speed, variation of turbine blades and interaction of wind speed and variation of turbine blades to the power capacity generated by Vertical Axis Wind Turbine (VAWT) using NACA 2412 and to stratify the power capacity generated by the VAWT simulation. The research backgrounds are the wind-energy potential in Indonesia is about 9.290 MW and has already elaborated by Ministry of Mining, and Energy Resources is about 50 MW. This wind energy is environmentally (clean energy), economically (cheapest), easy to operate and easy to maintain, also renewable energy. The method of analysis is quantitative approach using two way classification (analysis of variance or design of experiments). The research variables are wind speed, variation of turbine blades and this interaction among independent variables and the power capacity as dependent variables. Data wind speed simulation vary from 3 m/s till 6 m/s. The quantity of turbine blades vary from 3 till 8 units. The finding from this research is accepted the null hypothesis or not differ significantly at 5% from each independent variable. The scenario and the parameters during the strategy development use turbine blades, wind speed and power generated by VAWT and the maximum power generated is 16.38 watt. The wind speed is 6 m/s and the number of turbine blade is 4 units. However, the minimum power generated by VAWT is 0.45 watt, the wind speed is 6 m/s and the number of turbine blade is 3 units.

Keywords: *VAWT; NACA 2412; Wind Speed; Turbine Blades; Power; Renewable Energy.*

1. Introduction

The Indonesian energy consumption is increasing very rapidly, especially consumption energy for industries, transportation, commercial buildings and household sector (see Table 1), because of population growth, and economic growth energy.

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: http://www.esdm.go.id/. Accessed on July 16, 2015[6].

The fuel or energy consumption increases rapidly but decreases the fuel production (see Fig. 1), so the gap between the fuel or energy consumption and fuel production is wider, it means the government should import the fuel from other countries more than 150.000 bpd in 2014 and increasing the fuel subsidy (http://www.kompas.com/. Accessed on July 4, 2015)[7]. The decreasing of the deposit/stock of the fossil fuel, the increasing price of the crude oil, the increasing need for the crude oil, the need for the alternative energy or renewable energy (see Fig. 1).

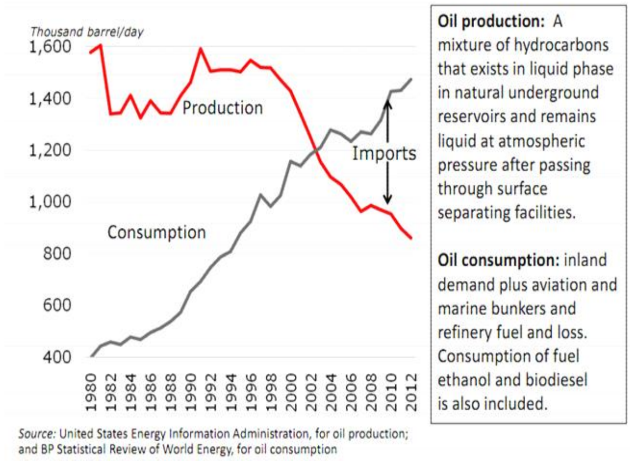

Fig. 1: Oil Production and Oil Consumption [5].

Many countries tried to generate or shift an alternative energy from nonrenewable 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. Concerning with the pollution, the content of the exhaust gas or the emission of the exhaust gas from the public transportation and private cars, commercial buildings, industries, and the households sectors tend to increase (see Table 1). Table 2 shows us the potential energy and energy stock that have not been explored efficiently and effectively.

Table 2: Stock and Energy Production in Indonesia Year 2007 (Non fossil Energy)

No.	Non fossil Energy	Energy Potential	Available capacity
1.	Hydro power	75,67 GW (e.q. 845 juta SBM)	4,2 GW
2.	Geothermal	27 GW (e.q. 219 juta SBM)	0,8 GW
3.	Mini/micro hydro	0,45 GW	0,084 GW
4.	Bio-mass	49,81 GW	0,3 GW
5.	Solar energy	4,8 kWh/m2/day	0,008 GW
6.	Wind energy	9,29 GW	0,0005 GW
7.	Uranium *)	3 GW (e.q. 24,112 ton)	30 GW

Note: *) Only in Kalian – West Kalimantan.
Source: Partowidagdo, W, 2010:532[15].

The stock and production of wind energy is more than 9,290 MW, what has been done and what has already been produced is about 50 MW. At present the government of the Republic of Indonesia is still installing the horizontal axis wind turbines (HAWT) that produces about 50 MW (30 units) in Yogyakarta – the Samas beach – Centre Java. It means the government has already started to promote the green technology (http://www.kompas.com/. Accessed on July 4, 2015, and http://www.ebtke.esdm.go.id/. Accessed on July 16, 2015)[7][8].

Table 3: The Development of Fuel Subsidy (2011-2013) [Rp. 10^{12}]

No.	Type of subsidy	2011	2012	2013
1	Fuel, LPG, Alternative energy	165.16	211.90	193.80
2	Public electricity	90.45	94,58	80,94
Total		245.61	306.48	274.74

Source: http://www.kompas.com/. Accessed on July 4, 2015 and Partowidagdo, W, 2010:532[7][17].

The objectives of this research is to analyze the effects of the wind speed, the number of turbine blades and interaction of the wind speed and the number of turbine blades to the power generated by Vertical Axis Wind Turbines (VAWT) using NACA 2412 (Seetharam, HC, and EJ Rodgers and WH Wentz, Jr. 1977, and Veers, PS. 1983)[16][17] and to stratify the power generated by the VAWT simulation.
Table 3 shows us the increasing of the government financial support for fuel subsidiary every year.

2. Theoretical background

This section discusses the airfoil, NACA 2412, and turbine blade. 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 (Figures 2, 3 and 4).

2.1. 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.

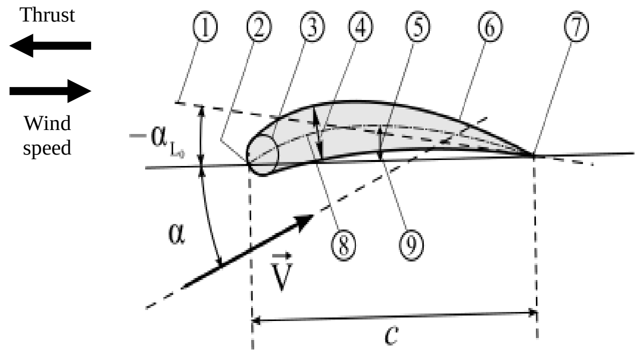

Fig. 2: Profile Geometry Airfoil [2], [12].

1: Zero lift line; 2: Leading edge; 3: Nose circle; 4: Camber; 5: Max thickness; 6: Upper surface; 7: Trailing edge; 8: Camber mean-line; 9: Lower surface

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 (Figures 2, 3 and 4). 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. The component parallel to the direction of motion is called drag (Figure 3).

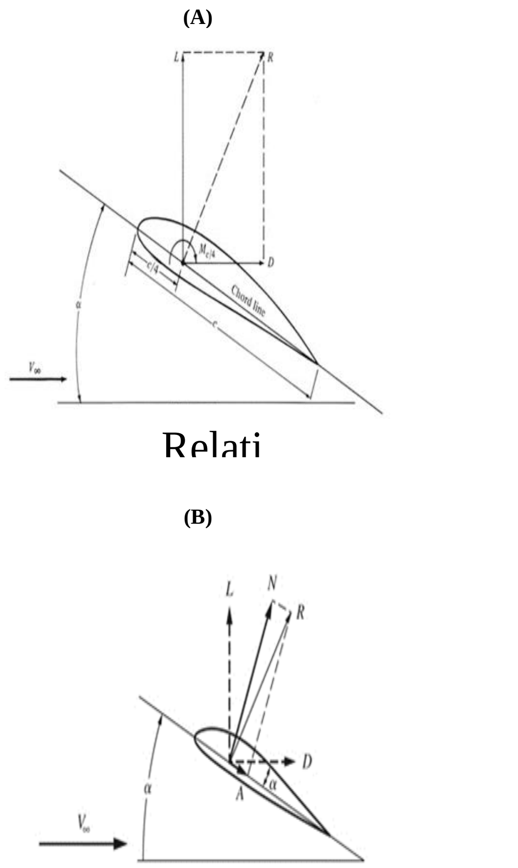

Fig. 3: Lift, Drag and Resultant Force (A) Lift and Drag, Moments, Angle of Attack and Relatif Wind; (B) Normal and Axial Force.

Source: http://www.en.wikipedia.org/wiki/simulation. Accessed on July 16, 2015.[11].

2.2. Simulation

Simulation is the imitation of the operations of various kinds of real-world facilities or processes or system. The act of simulating something first requires that a model be developed; Model represents the form of mathematical or logical relationships; this model represents the key characteristics or behaviors/functions of the selected physical or abstract system or process. The model represents the system itself, whereas the simulation represents the operation within the system (see Figure 5). Simulation is used in many contexts, such as simulation of technology for performance optimization, safety engineering, testing, training, education, and video games. Often, computer experiments are used to study simulation models. Simulation is also used with scientific modeling of natural systems or human systems to gain insight into their functioning. Simulation can be used to show the eventual real effects of alternative conditions and courses of action (http://www.en.wikipedia.org/ wiki/simulation. Accessed on July 16, 2015 and Laws AM and W David Kelton. 1982) [11].

2.3. Strategy

The terminology of strategy is strategos (Greek) which is the combination from two words "stratos" means "army" and "ago" means "leading/guiding/moving to". So the strategy means the art of the military operation planning and management in big scale and to direct to benefit position before the real battle with the enemy occurred. Wheelen (Wheelen, T L., and Hunger, JD. 2004) stated that "A strategy of a corporate forms a comprehensive master plan stating how the corporation will achieve its mission and objectives."[19].

2.4. Scenario

Scenario is an imagined or projected sequence of events, especially any of several detailed plans or possibilities: One scenario calls for doubling profits by increasing our advertising, the other by reducing costs.

3. Proposed method

The research variables are the wind speed, the number of the turbine blades, and the interaction of the wind speed and the number of the turbine blades as independent variables, and the power generated by Vertical Axis Wind Turbines (VAWT) using NACA 2412 as a dependent variable. The mathematical model (Hicks, CR. 1982) [5] is.

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

This research applies quantitative approach using factorial experiments. The data of wind speed vary from 3.5 m/s to 6 m/s. The number of the turbine blades vary from using 3, 4, and 6 units of turbine blades. Tests of hypotheses: the null hypotheses are accepted if the means from the variables data are not different significantly at the level 5%, and the null 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 the digital anemometer, whereas the power is a multi-testers (W=V×A or volt times ampere).

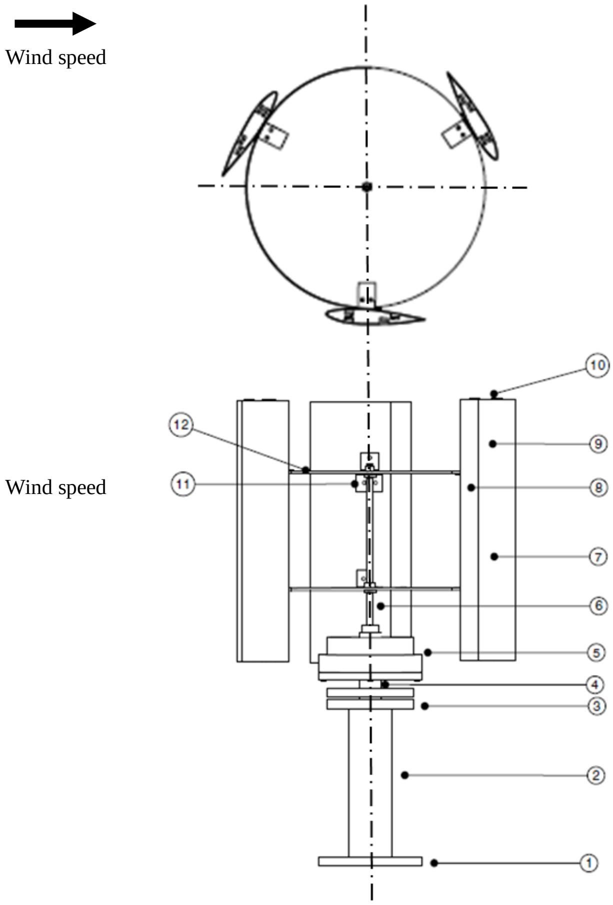

Fig. 4: Turbine Blades VAWT 1. Flange; 2. Shaft; 3. Flange; 4. Pipe; 5. Magnet Generator; 6. Shaft; 7. Blades; 8. Blades' Frame; 9. Shield; 10. Airfoil Aluminium Sheet; 11. Bracket; 12. Al Sheet Blades' Disk).

3.1. Development strategy

Table 6 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 is 16.38 watt, the wind speed is 6 m/s and the number of turbine blade is 4 unit and the minimum power generated by VAWT is 0.45 watt, the wind speed is 6 m/s and the number of turbine blade is 3 unit (see Table 6 and Figure 4).

4. Result and discussion

The F ratio is bigger than F table (see Table 5) or 4.53 > 2.61, it means the null hypothesis is rejected or the average wind speed to the power generated by VAWT is different significantly at 5%. The F ratio is bigger than F table (see Table 5) or 16.52 > 2.84, it means the null hypothesis is rejected or the average number of turbine blade to the power generated by VAWT is different significantly at 5%. The F ratio is bigger than F table (see Table 5) or 152.39 > 2.00, it means the null hypothesis is rejected or the average of interaction between wind speed and the number of turbine blade to the power generated by VAWT is different significantly at 5%. Table 7 shows us the scenario and the parameters of the strategy development which uses turbine blades, wind speed and power generated by VAWT and the maximum power generated by VAWT is 16.38 watt, the wind speed is 6 m/s and the number of turbine blade is 4 unit and the minimum power generated by VAWT is 0.45 watt, the wind speed is 6 m/s and the number of turbine blade is 3 unit (see Table 6 and Figure 6).

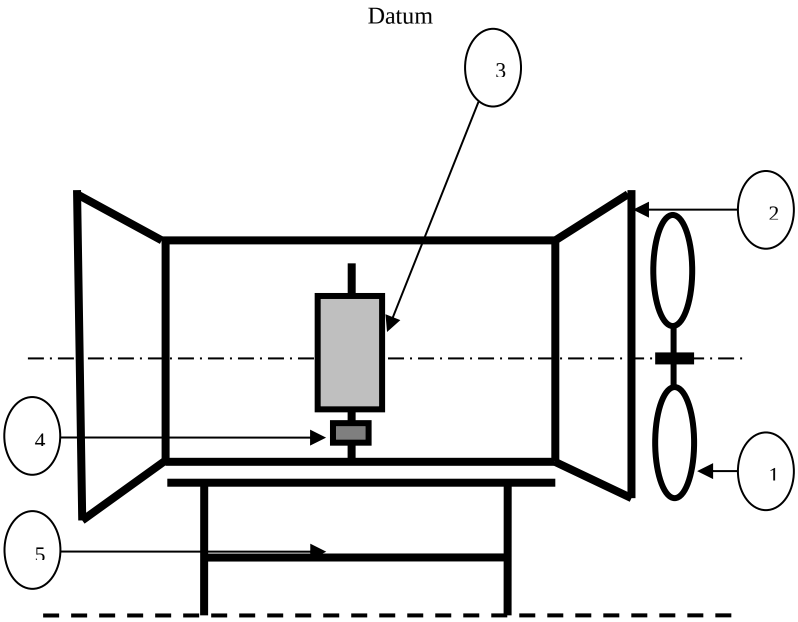

Fig. 5: Wind Tunnel (1. Blower; 2. Wind Tunnel; 3. Turbine Blades; 4. Generator; 5. Table).

Table 4: Wind Speed [M/S], Turbine Blades [Unit], and Power [Watt]

Turbines Blades	Wind Speed [m/s]				
	3.5	4	5	5.5	6
3 blades	1.68	0.8	0.68	0.54	0.37
	0.92	1.6	0.6	0.96	0.58
	1.6	1.52	0.6	0.91	0.55
	1.76	0.72	0.64	0.46	0.29
4 blades	7	6.4	8.04	17.6	16.4
	7	7.68	12.4	13	14.4
	7	7.44	13.4	11.34	17.5
	7	7.92	8.4	11.75	17.2
6 blades	1.62	1.44	1.8	4.8	6.96
	2	1.38	1.86	6	6.96
	1.84	1.5	1.8	5.4	5.2
	2	1.44	1.86	5.2	6.24

Source: Research data processed (Hicks, CR.1982)[5].

Table 5: Anova Results

Source	df	SS	MS	F ratio	F table
Between Factor WS	4	183.33	45.83	31.23	2.61
Between Factor TB	3	1,097.67	365.89	249.31	2.84
WS by TB interaction	12	160.73	13.39	9.13	2.00
Error	40	58.70	1.47		
Totals	59	1,500.44			

Source: Research data processed (Hicks, CR.1982)[5].

Table 6: The Average of Wind Speed [M/S], Turbine Blades [Unit], and the Average of Power [Watt]

Turbine Blades	Average Wind speed [m/s]				
	3.5	4	5	5.5	6
3 blades	1.49	1.16	0.63	0.72	0.45
4 blades	7.00	7.36	10.56	13.42	16.38
6 blades	1.87	1.44	1.83	5.35	6.34

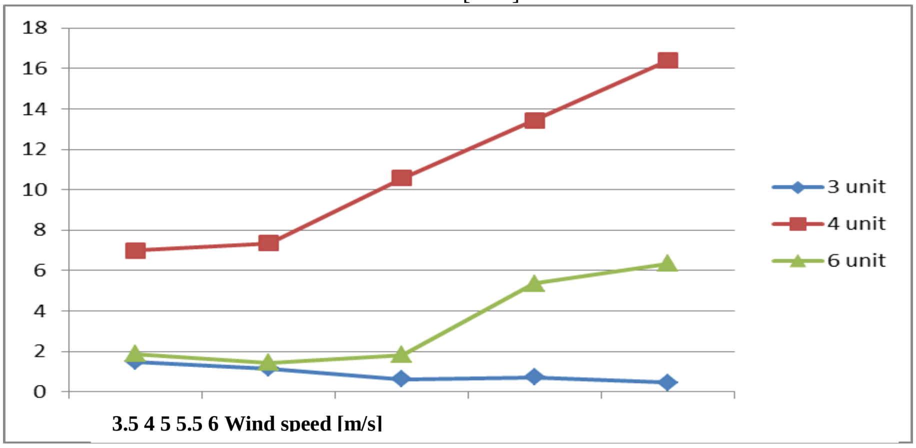

Fig. 6: Wind Speed, Power and Number of Turbine Blades.

Source: Research data processed (Hicks, CR.1982)[5].

Table 7: The Strategy Development [3]

No	Strategy	Alternative	Remark
1	Scenario 1	The maximum power generated by VAWT uses 4 unit of turbine blades, the wind speed is 6 m/s, and the power generated by VAWT is 16.38 watt.	The base line is 4 unit of turbine blades.
2	Scenario 2	The minimum power generated by VAWT uses 4 unit of turbine blades, the wind speed is 5.5 m/s, and the power generated by VAWT is 7 watt.	The base line is 4 unit of turbine blades.
3	Scenario 3	The maximum power generated by VAWT uses 6 unit of turbine blades, the wind speed is 6 m/s, and the power generated by VAWT is 6.34 watt.	The base line is 6 unit of turbine blades.
4	Scenario 4	The minimum power generated by VAWT uses 6 unit of turbine blades, the wind speed is 4 m/s, and the power generated by VAWT is 1.44 watt.	The base line is 6 unit of turbine blades.
5	Scenario 5	The maximum power generated by VAWT uses 3 unit of turbine blades, the wind speed is 3.5 m/s, and the power generated by VAWT is 1.49 watt.	The base line is 3 unit of turbine blades.
6	Scenario 6	The minimum power generated by VAWT uses 3 unit of turbine blades, the wind speed is 6 m/s, and the power generated by VAWT is 0.45 watt.	The base line is 3 unit of turbine blades.

5. Conclusions

The F ratio is smaller than F table. It means the null hypothesis is accepted or is not different significantly at 5% from each independent variable. The scenario and the parameters during the strategy development use turbine blades, wind speed and power generated by VAWT and the maximum power generated is 16.38 watt. The wind speed is 6 m/s and the number of turbine blade is 4 units. However, the minimum power generated by VAWT is 0.45 watt, the wind speed is 6 m/s and the number of turbine blade is 3 units.

Acknowledgment

The authors wish to express their gratitude to the Ministry of Research, Technology and Higher-Education – Republic of Indonesia and The Director of State Polytechnics of Malang for their support.

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