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PORTABLE WIND TURBINE USING BLADE TYPE INVERSE TAPER

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Abstract—**The electrical energy is greatly needed in human's life and even in the primary life of Indonesian. One of the renewable electrical energy resources is the wind energy which can be obtained by constructing a Wind Power Plant (PLTB, Pembangkit Listrik Tenaga Bayu). PLTB works by conversing the wind energy into electrical energy. PLTB that has been applied in Indonesia is using a permanent system with various kinds of blades. In this study, the Portable Wind Turbine is designed by using the inversed taper type blade. The Portable Wind Turbine consists of the inverse taper type wind turbine, DC dynamo, control circuit, and battery. The design begins with creating a simulation to design the turbine and control circuit. The turbine design uses Qblade and SolidWorks software for students, while the control circuit uses free version of Proteus software. The design result is a prototype which possesses a blade with 15cm and 8cm radius. The prototype testing is carried out by comparing two types of blade using various speed of artificial wind. The blade with 15cm length indicates a better result compared to the blade with 8cm. It produces a maximum voltage with the wind speed of 7m/s with 4,35volt and the current of 1,3 ampere.**

Index Terms — **Electrical Energy, PLTB, Wind Turbine, Inversed Taper**

I. INTRODUCTION

There is much alternative energy in Indonesia that can be utilized to generate electrical energy. One of them is wind energy. The wind energy is easy to acquire especially in coastal areas. The electrical energy is not solely produced by nature. A certain tool that can work and produce electricity well is required to harness the wind energy. That certain tool is a windmill. According to Meteorology Climatology and Geophysics Council (BMKG, Badan Metereologi Klimatologi dan Geofisika), Indonesia in 2018 had the wind speed average of 3m/s which potentially to have Wind Power Plant (PLTB, Pembangkit Listrik Tenaga Bayu) built in a small scale. The Wind Power Plant is a working system that converts the wind energy to be able to rotate the generator for producing electricity. Based on the nature of renewable wind energy and the diminishing supply of fossil energy, the research and development on the use of renewable energy must be in accordance with the needs of geographical location.

Generally, PLTB is built with a tower and turbine in a big scale. This is applied for the wind to be able to rotate the turbine thus it is able to generate large electricity. However, this power plant is not transportable or portable.

This study aims to design a small scale of PLTB for the need of emergency energy that is easily transportable. Since its design is simple, uncomplicated, and small, it is efficiently moveable. This Portable Wind Turbine (PWT) has a smaller frame shape compared to a commonly known power plant and it can be implemented to some area with low wind speed. This PWT can also be implemented to an automobile as a gadget charging during a trip. Other than that, PWT can as well be used as the energy source while doing outdoor activity like camping where there is no such thing as electrical resources or when natural disaster happened, PWT is going to be useful as the energy source for emergency lightning. PWT generates DC electrical energy which is utilized to charge some power into a cellphone, to turn some lamps on or any other life necessities that use DC electricity.

II. THE BLADE DESIGN

A. The Propeller Design

In this instrument design, the parameter for the propeller length and the need for power of 500 watt are determined as the design input base in Qblade. The prototype is designed to work with the wind speed ranging between 3m/s to 8m/s.

The design for propeller sweep width uses the equation number 1 below:

$$A = \frac{2P_a}{\rho . V_{max}^2} \quad (1)$$

With A is the width of propeller sweep (m^2), P_a is the wind power needed (watt), ρ is the air density (1.225 kg/m^3) and V_{max} is the maximum wind speed.

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The blade design of the propeller is divided into several elements whose functions are to provide the design accuracy and convenience during the construction process of prototype. In several references, there are many blade elements with the airfoil between 10 to 20 elements. The elements value is generated from the division between the blade radius (R) with the total of elements (n). r is a partial radius (each of the element) as in figure 1.

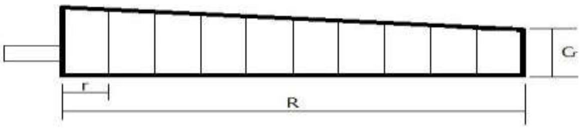

Figure. 1. The Division of Blade Elements

A flow angle is an angle in between relative wind direction and rotor rotation field. A flow angle affects the rotor rotation speed. The wider the angle is, the larger the turbulence is going to be. This turbulence can obstruct the rotor rotation. According to certain references, a good flow angle is within a range that is less than 50 by using the equation number 2.

$$\Phi = \frac{2}{3} tan^{-1} n \frac{1}{\lambda r} \quad (2)$$

With Φ is the flow, λr is the comparison of the blade elements linear speed against the wind speed in the element 1 up to the-n. and λ is a value of Tip Speed Ration (TSR) used.

The chord (Cr) line length must be determined in each of the blade elements. The chord length is going to be different in the event that designing the taper blade type and inversed taper by using the equation 3 below.

$$C_r = \frac{16.\pi.R.(\frac{R}{r})}{9.\lambda^2.B.C_l} \quad (3)$$

With B is the number of blade and CL is a coefisien lift.

III. Experiment Result

The next step is all the parameters are inputted into the Qblade software to be simulated and generated the characteristics and performance. In this study, the propeller is divided into 5 elements with a consideration that the prototype design is used for a small capacity as shown in Figure 2.

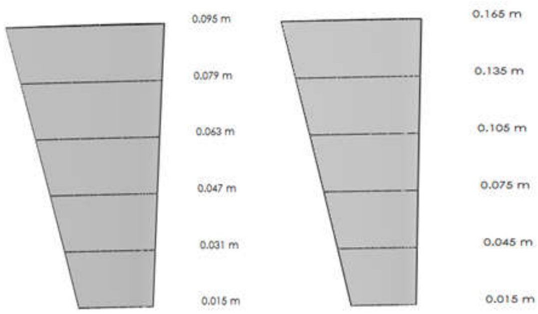

Figure. 2. The Distribution of Blade Design Elements

TABLE I
BLADE TURBINE 8 CM

Element	r (cm)	TSR	α	Cr	Φ (^{0})
0	0.015	0.947	6	0.025	31.032
1	0.031	1.958	6	0.030	18.037
2	0.047	2.968	6	0.035	12.412
3	0.063	3.979	6	0.040	9.405
4	0.079	4.989	6	0.045	7.555
5	0.095	6.000	6	0.050	6.308

The result of propeller simulation for a blade with 8cm length is depicted in the table 1 and with 15cm length is depicted in table 2

Then, the determined coordinate of the blade is used to design which the result is shown in Figure 3

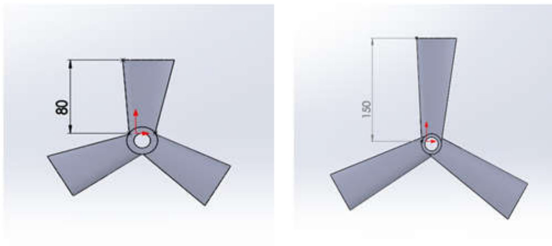

Figure. 3. The Blade Design Simulation

TABLE II
BLADE TURBINE 15 CM

Element	r (cm)	TSR	α	Cr	Φ (^{0})
0	0.015	0.545	6	0.030	40.926
1	0.045	1.636	6	0.036	20.953
2	0.075	2.727	6	0.042	13.424
3	0.105	3.818	6	0.048	9.784
4	0.135	4.909	6	0.054	7.676
5	0.165	6.000	6	0.060	6.308

A. Designing the Control Circuit

The control circuit is designed in a simple way but it produces output in accordance to one's desired design as shown in Figure 4. The component used in R_1 is 1 ohm 2 watt, R_2 is 10 ohm 2 watt, C_1 is 1000uF 50 volt, C_2 is 470uF 35volt, Q_1 is TIP 2955 and Regulator 78xx

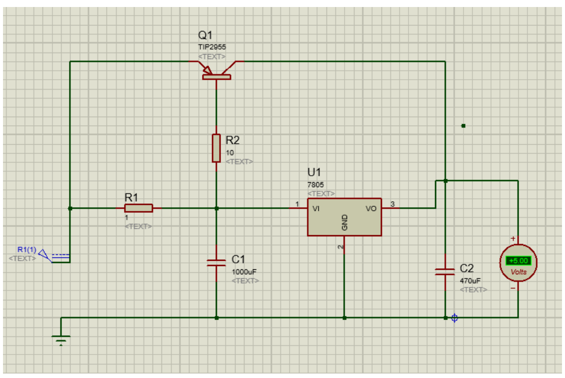

Figure. 4. The Blade Design Simulation

B. Designing The Box

Designing the box is adjusted to the size of assembled components as it is shown in Figure 5

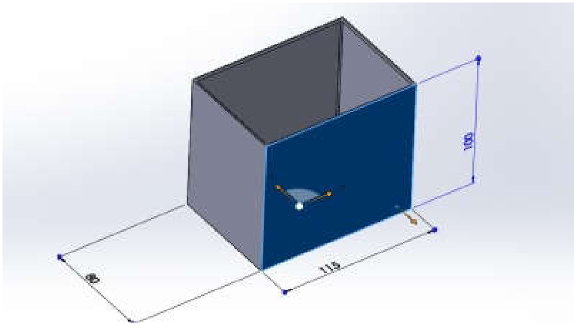

Fig. 5. Box Design

C. Creating the Propeller

The first step is creating or printing the turbine. In this process, the turbine is printed by using 3D printing with Polylactic Acid as the material in accordance with its dimension and it is shown in Figure 6

Figure 6. . The Blade Prototype

The initial experiment of the prototype is carried out partially in order to ensure that all the components are functioning well and then they are assembled altogether as shown in Figure 7.

Figure. 7. The Portable Wind Turbine Prototype

In that figure, if the indicator lamp turns green, it indicates that the prototype is charging the battery and it works in accordance with the design.

In the experiment process, an aiding tool is used which is a fan to ease up the arrangement of the wind speed variation. The result of turbine testing is described in Table 3 and 4.

TABLE III
BLADE TURBIN 8 CM

wind velocity	blade rotation (rpm)	Voltage (volt)	charging current	Notes
2-3	148	2,02	0,23	Not charging
3-4	170	3,15	0,46	Not charging
4-5	210	3,54	0,86	Not charging
5-6	268	4,14	0,91	Not charging
6-7	475	4,30	1,31	Charging
7-8	567	4,54	1,47	Charging

In experiments with 8cm blade, it indicates that with 6-7m/s wind speed, the turbine rotation speed touches 475rpm with the generated voltage of 4.30 volt and this can be utilized for charging batteries with currents reaching 1.31 ampere. While for under 6m/s wind speed, the prototype is only capable to generate maximum turbine rotations of 268 with 4,14 voltage, but this cannot be utilized for charging batteries since its current is weak (<1 ampere).

TABLE IV
THE TURBINE BLADE 15 CM

wind velocity	blade rotation (rpm)	Voltage (volt)	charging current	Notes
2-3	257	3,87	0,88	Not Charging
3-4	348	4,22	1,27	Charging
4-5	475	4,38	1,31	Charging
5-6	616	4,94	1,11	Charging
6-7	700	5,37	1,34	Charging
7-8	778	5,53	1,65	Charging

In experiments with 15cm blade, it indicates that with 3-4m/s wind speed, the turbine rotation speed touches 348rpm with the generated voltage of 4.22 volt and this can be utilized for charging batteries with currents reaching 1.27 ampere. While for under 3m/s wind speed, the prototype is only capable to generate maximum turbine rotations of 257 with 3,87 voltage, but this cannot be utilized for charging batteries since its current is weak (<1 ampere).

The experiment result comparison between the wind speed against the blade rotation, the wind speed against the voltage, and the wind speed against the current are depicted in a graphic as shown in Figure 8, 9, and 10.

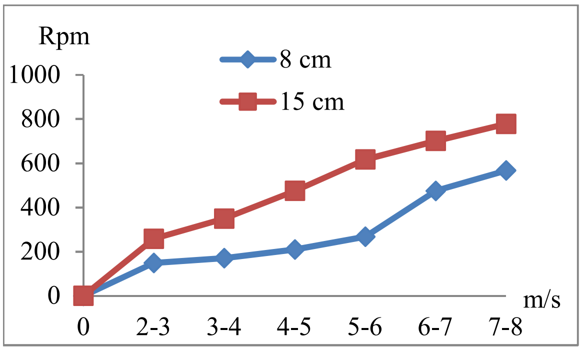

Figure. 8. The Portable Wind Turbine Prototype

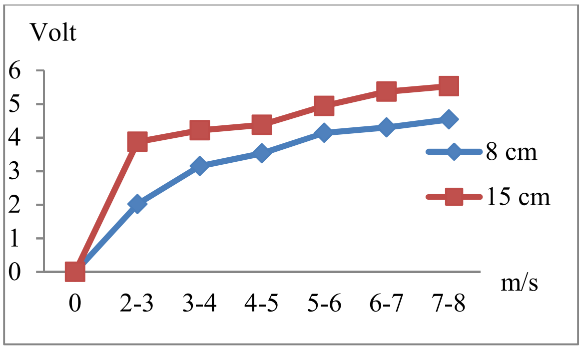

Figure. 9. The Portable Wind Turbine Prototype

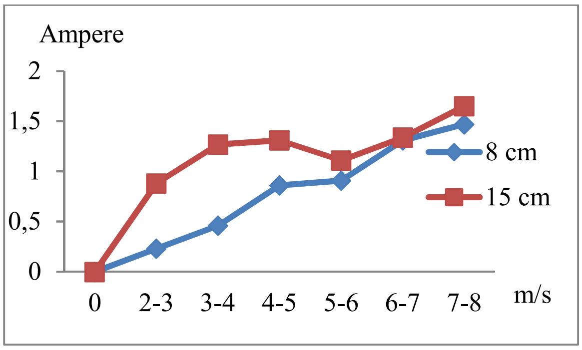

Figure. 10. The Portable Wind Turbine Prototype

While the 8cm blade only generates maximum rotation of 567rpm with the wind speed of 7-8m/s and voltage of 4,54volt with current of 1,47 ampere. Therefore, in the event that one should compare, the 15cm blade works better than the 8cm blade.

IV. Conclusion

The conclusion that can be derived from designing the portable wind turbine and testing the prototype is that the wind turbine with inversed taper type can be utilized as the wind turbine for a region that has low scale wind speed. The second conclusion is the longer blade that is being used, the faster the blade rotation is going to be thus if it is utilized to activate the generator, it is capable to produce decent voltage and current. The prototype experiment result indicates that the 15cm blade generates maximum rotation of 778rpm with the wind speed ranging from 7 to 8m/s and it generates voltage of 5,53volt with current of 1,65 ampere

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