Blade Design for Stand-Alone Room Lighting Powered by Wind Turbine

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Abstract— **The primary focus in this project is to design blade that can collect wind energy as maximum as possible. There are two types of blade design; vertical and horizontal where each type has its own advantage and disadvantages. Moreover, the number of blade, size and material used to design the blade is also will be studied. Simulation also been done to verify the effectiveness of the blade design in term of drag coefficient value. All those characteristics of blade should be study well to make the blade is able to collect as much as wind blow from home fan.**

I. INTRODUCTION

Wind turbines interact with the wind, capturing part of its kinetic energy and converting it into usable energy. This energy conversion is the result of several phenomena. The wind is characterized by its speed and direction, which are affected by several factors, *e.g.* geographic location, climate characteristics, height above ground, and surface topography.

The usage of wind energy is more effective compared to the other renewable energy such as sun source where sun UV only produces in bright day while wind can get when people used the fan. Each time the fan producing wind, the blade will rotate and ready to charge battery that will used as source to functioning room lamp.

Wind energy concept is similar to the hydro concept where when the water flow through the blade and shaft rotation will rotate the rotor in the generator [1]. But in the wind energy concept, the wind blowing with some speed will rotate the blade. In this process, there are three steps of energy converting involved, that are from kinetic energy (wind) convert to mechanical energy (rotor) and finally to electrical energy.

II. METHODOLOGY

The system of stand-alone wind turbine for room lighting is consisting of generation part, controller part, storage and load. This technical paper focused on blade design of the system. This part is very important because it responsible to collect the wind blowing for rotating generator to produce electric current.

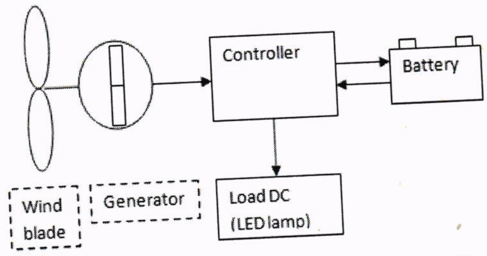

Figure 1 : Basic block diagram of Stand Alone Room Lighting Powered by Wind Energy.

The blade design starting with considers where it will apply and install. Vertical axis wind turbine is suitable compared to horizontal blade because vertical blade can rotate when wind blow in any direction [2]. Then do simulation to look the proper design that suitable to particular wind speed. It can be determine by compare the drag coefficient of each type of blade.

CATIA software is used to design blade and save the design in *igs* format that can be open in STAR CCM software for simulation process. From the simulation result, the drag coefficient shows whether the blade design is good to collect wind. Drag in general is a force that causes a resistance to motion. Drag force is the force develops parallel to the relative wind [3, 4]. Drag coefficient is the value used to show the capability of blade to capture the wind blowing and absorb the maximum force of wind or force of drag (1). The range of drag coefficient is from 0.00 to 2.50 [5, 6].

The blade is design follow to the higher value of drag coefficient and assembly all blade to the shaft. The blade is design to the variable numbers of blades for the experiment purpose such as five to ten blades.

Gear is required to install between blade and generator in order to increase the speed of generator. Gear should be design to get the desired output from generator based on rated speed of blade and wind. The gear must be to install to the any type of the wind turbine because the speed of blade is not much as desired by the user. Gear will be placed between blade shaft and generator shaft with right ratio design.

III. SIMULATION

The simulation process using STAR CCM software to measure the capability of blade absorbs the maximum wind blow or wind force [5]. The force will be defined by analysis the drag coefficient. There are several types of blade designed has been done the simulation process.

Types of blade:

1) *Drag-based wind turbine*

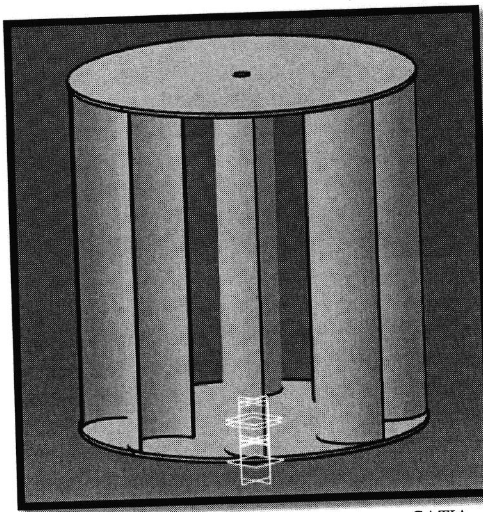

Figure 3: Drag-based wind turbine design on CATIA

2) *Savonius*

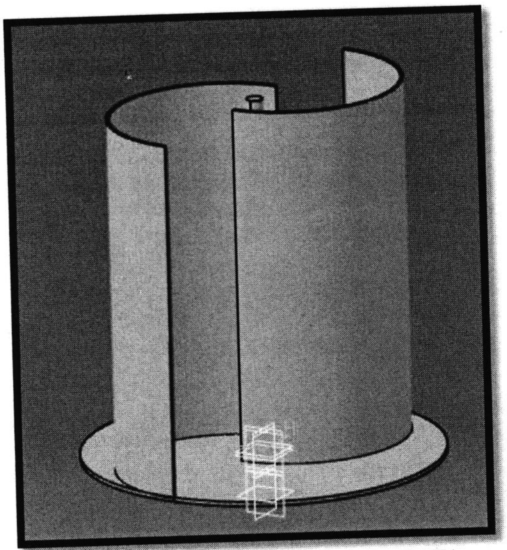

Figure 4: Savonius wind turbine design on CATIA

A. Simulation process

i. Design blade on CATIA (8 Blades)
ii. Save design with *igs* format
iii. Export *igs* file to the STAR CCM software
iv. Setting the require parameter.
v. Run simulation

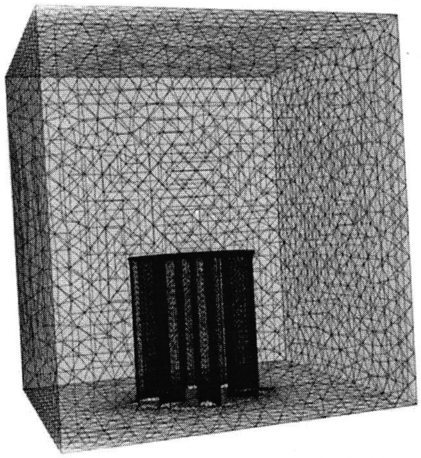

Figure 5: Blade on simulation process (in wind tunnel)

vi. Collect the result

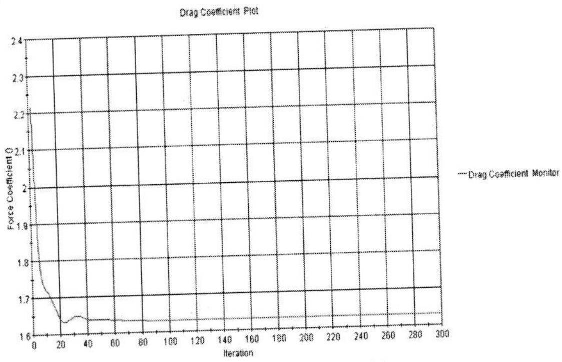

Figure 6: Drag coefficient, C_D

No of iteration : 300
C_D : 1.63

vii. Calculate the drag force

$$F_D = \frac{1}{2}\rho V^2 S C_D \quad (1)$$

Where; F_D=Drag force (N)
ρ =Density (kg/m^3)
V=Velocity (m/s)
S =Reference area (m^2)
C_D =Coefficient of Drag

$$F_D = \frac{1}{2}(1.164)(6.3)^2(0.03)(1.63)$$
$$= 1.13N$$

B. Results

All blade design has been simulated on STAR CCM. The results of simulated blades as follows:

1) Drag-based wind turbine

TABLE 1: SIMULATION RESULT OF DRAG-BASED WIND TURBINE

No of blade	Drag Coefficient	Drag force (N)
5	1.47	1.01
6	1.56	1.08
7	1.59	1.10
8	**1.63**	**1.13**
9	1.55	1.07

2) Savonius

TABLE 2: SIMULATION RESULT OF SAVONIUS WIND TURBINE

No of blade	Drag Coefficient	Drag force (N)
2	1.50	1.03

The blade can be design in any number of blades, but from the simulation result shows that 8 blades design have higher drag force. That force will turn the blade rotate with the maximum speed by wind speed of 6.3 m/s.

IV. HARDWARE CONTRUCTION

The blade has a good or higher drag coefficient is been construct for the experiment purpose. The data will be analysis and apply to the full system (controller, battery storage and load). The blade is testing the rotate the generator and supply power to the room and charge the rechargeable battery.

A. Blade design
- Vertical axis wind turbine (drag-based)
- Half cut of PVC pipe (Ø 90mm)
- 8 blades
- Size: Ø 40x40cm

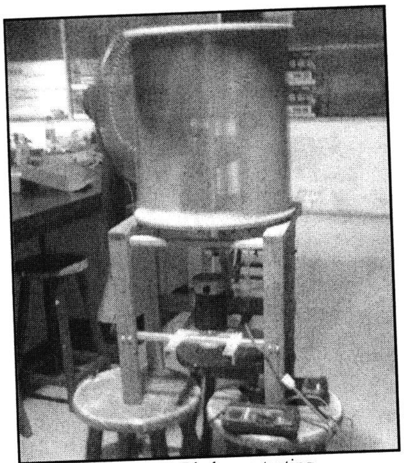

Figure 7: Blades on testing

B. Gear design
- Step-up ratio of 1:1.5 and 1:2

$$D = 2(m + 2) \quad (2)$$

Where; D = diameter of gear
m = number of teeth

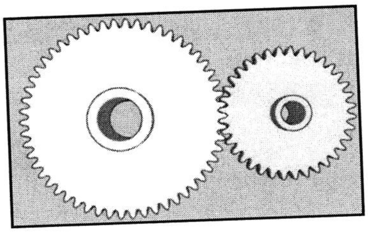

Figure 8: Pair of gear ratio 1:1.5

Gear can be design by apply equation 2 above. From the diameter of the gear, we can determine the no of gear's teeth.

C. Generator
- DC generator for wind turbine
- 20 VDC rated

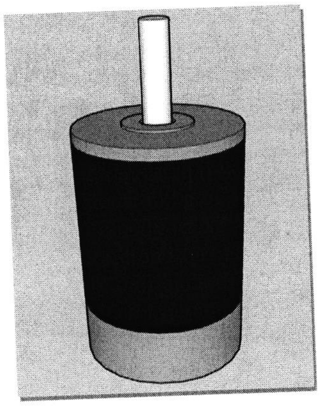

Figure 9: DC generator

V. RESULTS & DISCUSSION

The result is collected from the hardware experiment. The experiment does on drag-based vertical axis blade designs and gears using two types of stand-alone home fan. The test is carry in the bed room for the a few hours. The data collected will be analyzed to see whether the blade can produce the desired output voltage to charge battery and supply the lamp (LED) in the room.

A. Experiment on the blade (Room A)

- Room size : 12x6x8 feet
- Fan position : 0.5 meter

a. Module 1

Type of fan : Stand-alone (KHiND)

i. Experiment: No-load test (not connected to the generator)

TABLE 3: NO-LOAD TEST RESULT OF FAN 1

Fan control number	Wind speed (m/s)	8 blades speed (rpm)
0	0	0
1	4.20	168
2	5.30	196
3	6.30	215

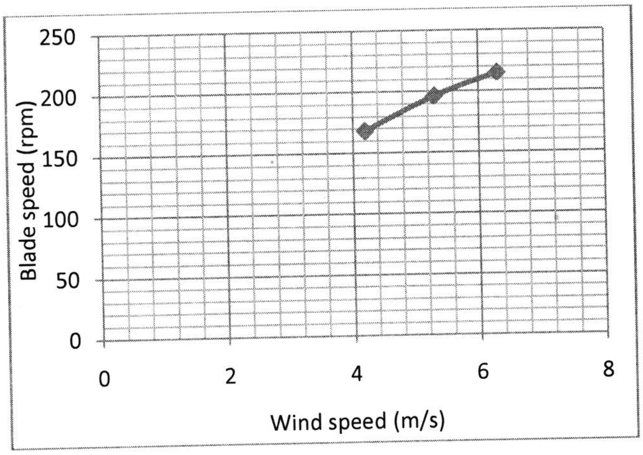

Figure 10: Blade speed versus wind speed

ii. Second experiment: With load test (connected to the generator)

Gear Ratio: 1:1.5

TABLE 4: WITH LOAD TEST RESULT

Fan control number	Wind Speed (m/s)	8 blades speed (rpm)	Generator Speed (rpm)	Output Voltage (V)
0	0	0	0	0
1	4.20	79	118.5	4.05
2	5.30	117	175.5	5.28
3	6.30	140	210	6.40

Gear Ratio: 1:2

TABLE 5: WITH LOAD TEST RESULT

Fan control number	Wind Speed (m/s)	8 blades speed (rpm)	Generator Speed (rpm)	Output Voltage (V)
0	0	0	0	0
1	4.20	59	118	4.01
2	5.30	87	174	5.17
3	6.30	104	208	6.38

b. Module 2

Type of fan : Stand-alone fan (SONIC)

i. Experiment: No-load test (not connected to the generator)

TABLE 6: NO-LOAD TEST RESULT

Fan control number	Wind speed (m/s)	8 blades speed (rpm)
0	0	0
1	3.78	162
2	5.14	190
3	6.20	211

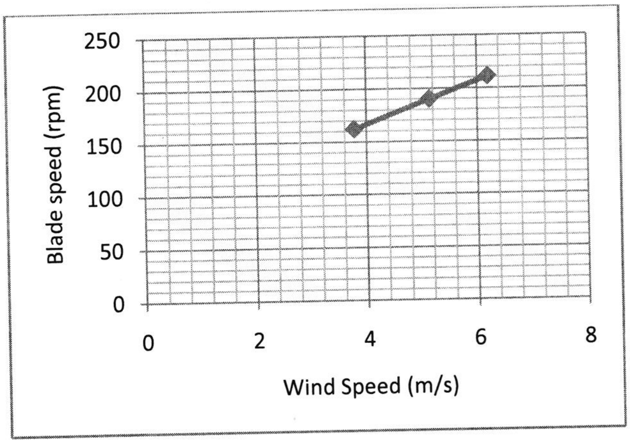

Figure 11: Blade speed versus wind speed

ii. Second experiment: With load test (connected to the generator)

Gear Ratio: 1:1.5

TABLE 7: WITH LOAD TEST RESULT

Fan control number	Wind Speed (m/s)	8 blades speed (rpm)	Generator Speed (rpm)	Output Voltage (V)
0	0	0	0	0
1	3.78	72	108	3.85
2	5.14	110	165	5.16
3	6.20	137	205	6.28

Gear Ratio: 1:2

TABLE 8: WITH LOAD TEST RESULT

Fan control number	Wind Speed (m/s)	8 blades speed (rpm)	Generator Speed (rpm)	Output Voltage (V)
0	0	0	0	0
1	3.78	56	112	3.94
2	5.14	84	168	4.96
3	6.20	102	204	6.20

c. *Simplification of module 1 and 2*

Module 1 and module 2 is simplified together to analyze the variation of the wind speed to the generator voltage.

i. Gear ratio of 1:1.5

TABLE 9: WITH LOAD TEST RESULT

Variation	Wind Speed (m/s)	8 blades speed (rpm)	Generator Speed (rpm)	Output Voltage (V)
1	3.78	72	108	3.85
2	4.20	79	118.5	4.05
3	5.14	110	165	5.16
4	5.30	117	175.5	5.28
5	6.20	137	205	6.28
6	6.30	140	210	6.40

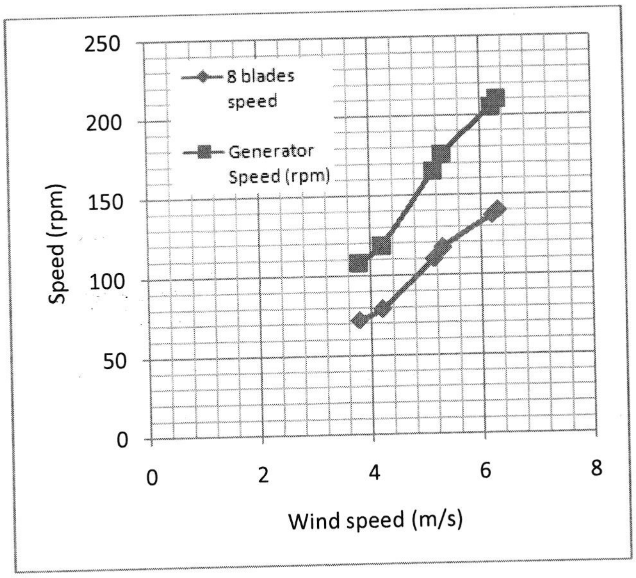

Figure 12: Generator and blade speed versus wind speed

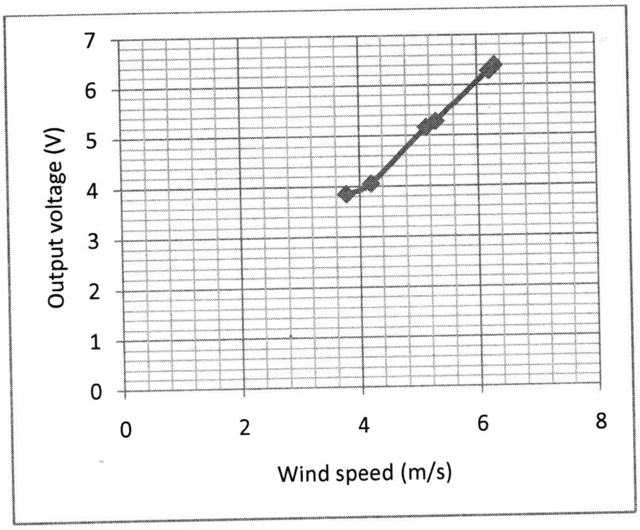

Figure 13: Output voltage versus wind speed

ii. Gear ratio of 1:2

TABLE 10: WITH LOAD TEST RESULT

Variation	Wind Speed (m/s)	8 blades speed (rpm)	Generator Speed (rpm)	Output Voltage (V)
1	3.78	56	112	3.94
2	4.20	59	118	4.01
3	5.14	84	168	4.96
4	5.30	87	174	5.17
5	6.20	102	204	6.20
6	6.30	104	208	6.38

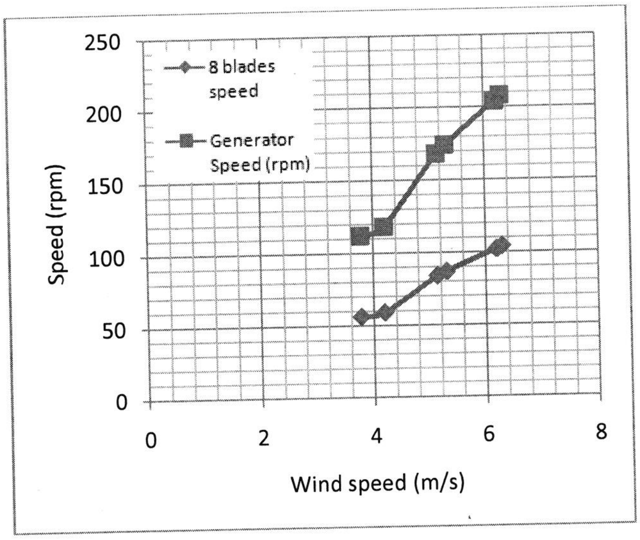

Figure 14: Generator and blade speed versus wind speed

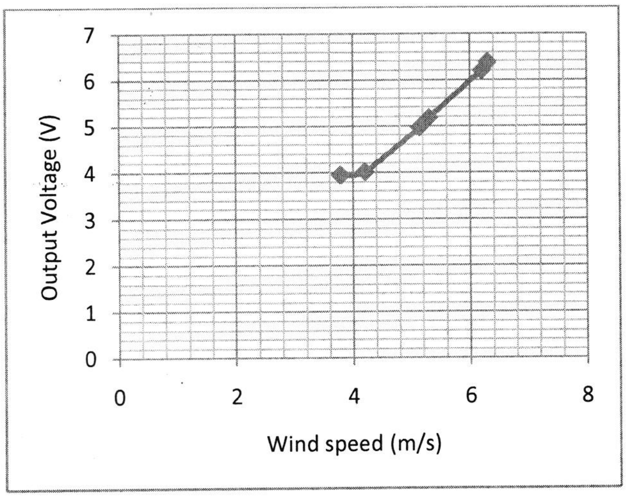

Figure 15: Output voltage versus wind speed

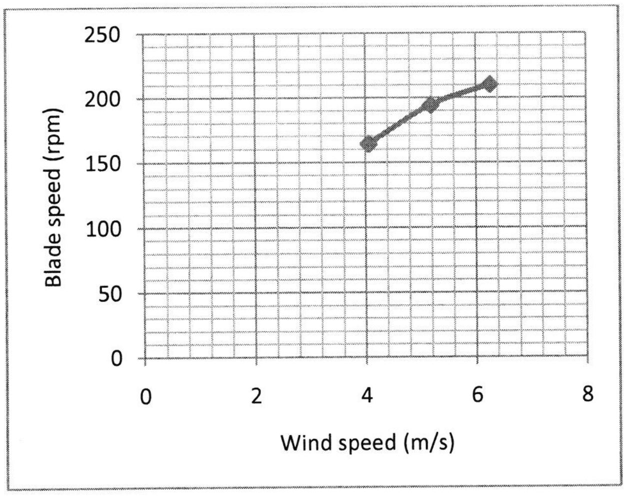

Figure 16: Blade speed versus wind speed

All figures show that the curve did not start at zero but start increasing at certain point because the blade or system only will give the result when the fan is start running at level 1 and so on.

During test running on the blade that not connected to the generator shaft, the speed of blade is very high about 215 rpm (fig. 10). The speed can achieve to that level because it no influence by the generator torque [7]. While in order to get the voltage from generator, the blade must be attach to the generator by using gears. After test two types of gear ratio, we can see that the final voltage is almost same (fig. 13 & 15). This is because when we test the gear ratio of 1:2, the speed of blade is slow down due to the high torque by generator (fig.12 & 14). To increase the output voltage, we must increase the wind speed.

B. Experiment on blade (Room B)

- Room size : 20x10x8 feet
- Position : 0.5 meters

a. Module 1

Type of fan: Stand-alone fan (KHiND)

i. Experiment: No-load test (not connected to the generator)

TABLE 11: NO-LOAD TEST RESULT

Fan control number	Wind speed (m/s)	8 blades speed (rpm)
0	0	0
1	4.06	164
2	5.18	194
3	6.25	210

ii. Second experiment: With load test (connected to the generator)

Gear ratio: 1:1.5

TABLE 12: WITH LOAD TEST RESULT

Fan control number	Wind Speed (m/s)	8 blades speed (rpm)	Generator Speed (rpm)	Output Voltage (V)
0	0	0	0	0
1	4.06	79	118	4.00
2	5.18	117	176	5.21
3	6.25	138	207	6.32

Gear Ratio: 1:2

TABLE 13: WITH LOAD TEST RESULT

Fan control number	Wind Speed (m/s)	8 blades speed (rpm)	Generator Speed (rpm)	Output Voltage (V)
0	0	0	0	0
1	4.06	55	110	3.85
2	5.18	81	162	5.10
3	6.25	102	203	6.25

b. Module 2

Type of fan: Stand-alone fan (SONIC)

i. Experiment: No-load test (not connected to the generator)

TABLE 14: NO-LOAD TEST RESULT

Fan control number	Wind speed (m/s)	8 blades speed (rpm)
0	0	0
1	3.70	164
2	5.05	194
3	6.12	210

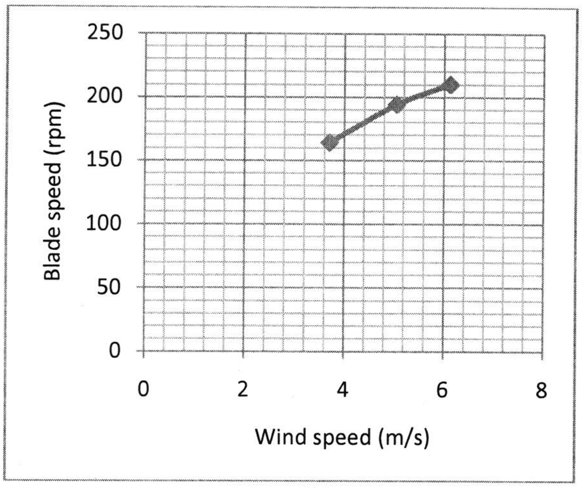

Figure 17: Blade speed versus wind speed

ii. Second experiment: With load test (connected to the generator)

Gear ratio: 1:1.5

TABLE 15: WITH LOAD TEST RESULT

Fan control number	Wind Speed (m/s)	8 blades speed (rpm)	Generator Speed (rpm)	Output Voltage (V)
0	0	0	0	0
1	3.70	73	110	3.81
2	5.05	108	162	5.10
3	6.12	135	203	6.20

Gear Ratio: 1:2

TABLE 16: WITH LOAD TEST RESULT

Fan control number	Wind Speed (m/s)	8 blades speed (rpm)	Generator Speed (rpm)	Output Voltage (V)
0	0	0	0	0
1	3.70	52	104	3.72
2	5.05	78	159	5.01
3	6.12	100	200	6.12

c. *Simplification of module 1 and 2*

Module 1 and module 2 is simplified together to analyze the variation of the wind speed to the generator voltage.

i. Gear ratio of 1:1.5

TABLE 17: WITH LOAD TEST RESULT

Variation	Wind Speed (m/s)	8 blades speed (rpm)	Generator Speed (rpm)	Output Voltage (V)
1	3.70	73	110	3.81
2	4.06	79	118	4.00
3	5.05	108	162	5.10
4	5.18	117	176	5.21
5	6.12	135	203	6.20
6	6.25	138	207	6.32

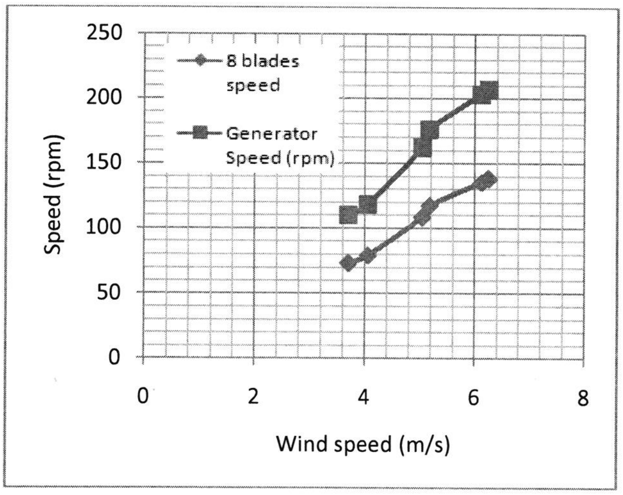

Figure 18: Generator and blade speed versus wind speed

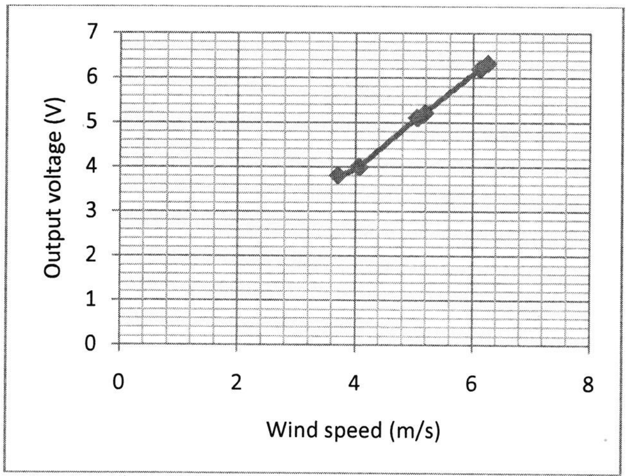

Figure 19: Output voltage versus wind speed

ii. Gear ratio of 1:2

TABLE 18: WITH LOAD TEST RESULT

Variation	Wind Speed (m/s)	8 blades speed (rpm)	Generator Speed (rpm)	Output Voltage (V)
1	3.70	52	104	3.72
2	4.06	55	110	3.85
3	5.05	78	159	5.01
4	5.18	81	162	5.10
5	6.12	100	200	6.12
6	6.25	102	203	6.25

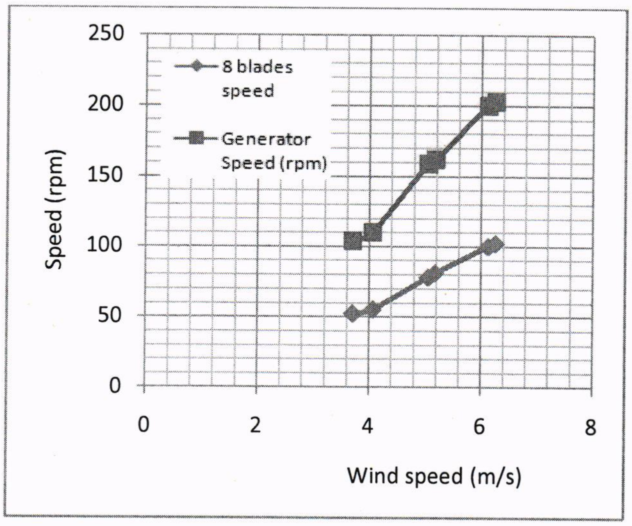

Figure 20: Generator and blade speed versus wind speed

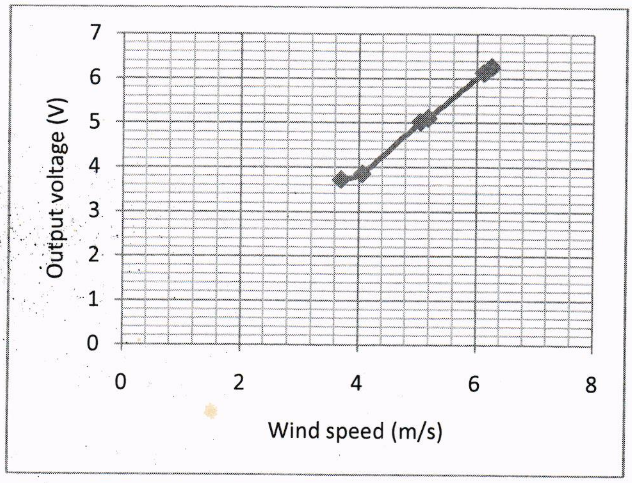

Figure 21: Output voltage versus wind speed

Compare result from part A & B, we can see that the difference size of room can effected the speed of wind. This is because in the small room (Room A) the wind blowing from fan will be focus straight to the blade. The speed of wind is very maximum when push the blade. Room B is bigger than Room A, the effect of wind will spread to the other open space and lees speed will be push the speed. We can see those differentiate by looking on Table 9 & 17, it shows at the 6th variation the output voltage of Room A and Room B are 6.4 V and 6.32 V respectively.

The battery of 6 volts can be charge by the generator voltage at the fan level of number 3 because the process of charging start when the supply is greater the battery voltage.

VI. Conclusion

Vertical axis wind turbine is the good design because it can absorb maximum wind force that will rotate the blade. The design is suitable to apply on the stand alone fans that have high wind speed. The wind speed of fan is able to rotate the blade and also generator that finally can be use to charge the battery that supply the room lighting. The size of blade is suitable to the desired output voltage. If users want the more power, they must consider getting the blade that has large space to capture wind because the power can be varies by the size blade to capture wind [6].

This type wind turbine is suitable to apply at the small room to get the maximum wind speed on the blade. But other room size is also can be used, but the output voltage will be drop about less than 15 percent. From the experiment on two sizes of room, the blade is good enough to charging the 6 volts battery that used to supply the LED.

VII. References

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