Micro Wind Turbine as the Power Supply for Micro Unmanned Aerial Vehicle

By

Mohd Aliff Omar bin Haris

Dissertation Report submitted in partial fulfillment of
The requirements for the
Bachelor of Engineering (Hons)
(Mechanical Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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BACHELOR OF ENGINEERING (Hons)
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Approved by,

____

(Ir Idris Ibrahim)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
December 2008

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MOHD ALIFF OMAR BIN HARIS

ABSTRACT

The objective of this project is to generate an uninterrupted power supply to operate the Micro Unmanned Aerial Vehicle (MUAV). MUAV is a small flying vehicle used for site observation since it is small, cheap and does not need a pilot to fly it. There are lots of energy sources can be extracted to produce energy to operate the MUAV. For instance, when the MUAV is flying at the high altitude, there are high speed wind, sunshine, vibration from the MUAV and many more sources of energy that should never been wasted. This project is about studying those sources of energy and design a system that will provide enough power for the MUAV to operate without having a limited power supply problem. After comparing all of the design, wind turbine has been selected as the best power supply for MUAV. The design of the micro wind turbine has been finalized and some analysis and simulation process had been undertaken. Final result shows that the new system can increase the flight time of the MUAV by 40% compared to the old system without the Micro Wind Turbine to recharge the Lithium Battery.

ACKNOWLEDGEMENT

I would like to take this opportunity to acknowledge and thank everyone that has given me all the supports and guidance throughout the whole period of completing the final year project. Firstly, many thanks to the university and the Final Year Project coordinators that have coordinated and made the necessary arrangements for this study.

I must also acknowledge the endless help and support received from my supervisor, Ir Idris Ibrahim throughout the whole period of completing the final year project. His guidance and advices are very much appreciated.

Finally, many thanks to my fellow colleagues and to all individuals that has helped in any way, but whose name is not mentioned here; for their help and ideas throughout the completion of this study. Thank you all.

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CHAPTER 1
INTRODUCTION

1.1 Background Study

A micro unmanned aerial vehicle (MUAV) also known as a remotely piloted vehicle or RPV, or Unmanned Aircraft System (UAS) is an aircraft that flies without a human crew on board the aircraft. Their largest uses are in military applications. To distinguish UAVs from missiles, a MUAV is defined as a reusable, uncrewed vehicle capable of controlled, sustained, level flight and powered by a jet or reciprocating engine. There is a wide variety of UAV shapes, sizes, configurations, and characteristics. Historically, MUAVs were simple drones (remotely piloted aircraft), but autonomous control is increasingly being employed in MUAVs. MUAVs come in two varieties: some are controlled from a remote location, and others fly autonomously based on pre-programmed flight plans using more complex dynamic automation systems.

Nevertheless, a biggest problems faced by engineers designing the MUAV is the limited power supply of the MUAV. Since it is small in scale and there is no pilot on board, they need to design a power supply system that can operate the MUAV for a long time, more distance covered and maximize its functionality. There are many sources of energy that can be extracted during MUAV's flight and it will help supplying extra energy for the vehicle.

Main reasons for a MUAV to have long lasting power supply during flight:

1. Cover more area and long distance flight.
2. Fly for a longer period of time.
3. Backup power supply in case there are problems with the main power supply. This will prevent the MUAV from crashed.
4. Maximize its functionality. Perhaps can be used for offshore observation or rescue purpose.
5. Preserve the environment.

1.2 Problem Statement

Micro Unmanned Aerial Vehicle (MUAV) is designed so that the vehicle can fly and do observation without a pilot on board. One of the biggest problems faced is the limited power supply of the MUAV. The MUAV need a good power supply system so that it can cruise for a longer time, distance and maximize its functionality.

1.3 Objectives

Main objectives of this study are:

1. To study and research about all the previously used power supply and new sources of alternative energy that can be extracted to operate the MUAV.
2. To compare micro wind turbine with other alternative power supplies that can be used on the MUAV.
3. To design a power supply system for MUAV using micro wind turbine and maximize the power supply.
4. To simulate the system and investigate the maximum power that the system can supply.

1.4 Scope Of Study

Scope of this project is focusing on designing a micro wind turbine as power supply of a MUAV. The MUAV project consists of several job scopes that is manages by final year students in UTP. Some of the job scopes include designing and the fabrication of the MUAV. As for this project, it focuses deeply into developing the micro wind turbine to operate the MUAV and improves it further along the project period. The aim is to develop a good system that can be further improved in the future since there is not much research being done in using wind turbine as MUAV power supply.

CHAPTER 2
LITERATURE REVIEW

This technology of little wind-powered toy brings clean, green energy to the palm of your hand, and is a great little gadget for getting youngsters interested in the beauty of renewable energy. No batteries or charging or nothing – instead just blow on the toy and watch it light up! It can produce a little amount of power ranging between 2W to 3W.

The wind-powered toy has one green and two blue LED lights which are powered by blowing on the tiny 2.4-inch rotor blade. So you can forget using a lighter or cell phone during that ballad at your next rock concert— illuminate the night with the eco-friendly. If this turbine can light up 2 LEDs, it means that it can generate power reaching 1.0 Watt. [1]

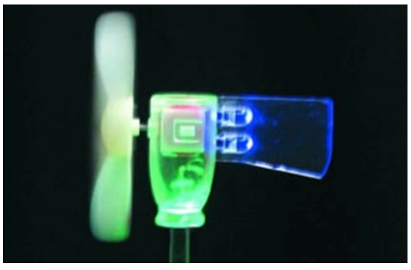


FIGURE 2.1: Smallest Wind Turbine

Important Design Variation For Wind Turbine [2]

1. Rotor diameter – larger rotor captures more energy but cost more.
2. Generator capacity – larger generator can capture more energy at high wind speed but also cost more.
3. Hub height – wind speeds increase with hub height but so does tower cost.
4. Rotor blade design – blade have a slight twist which can be optimized to capture the maximum amount of wind power.
5. Power control – active pitch or active stall.
6. Generator type – synchronous or asynchronous.
7. Speed – Fixed or variable

Basic Wind Turbine Formulae [3]

$$KineticEnergy(Joules) = \frac{1}{2}\dot{m}v^2 \qquad (1)$$

where:

m = mass (kg) (1 kg = 2.2 pounds)

v = velocity (meters/second) (meter = 3.281 feet = 39.37 inches)

Usually, we're more interested in power (which changes moment to moment) than energy. Since **energy = power x time and density** is a more convenient way to express the mass of flowing air, the kinetic energy equation can be converted into a flow equation:

Power in the area swept by the wind turbine rotor:

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

where:

P = power in watts (746 watts = 1 hp) (1,000 watts = 1 kilowatt)
ρ = air density (about 1.225 kg/m^3 at sea level, less higher up)
A = rotor swept area, exposed to the wind (m^2)
v = wind speed in meters/sec (20 mph = 9 m/s) (mph/2.24 = m/s)

This yields the power in a free flowing stream of wind. Of course, it is impossible to extract all the power from the wind because some flow must be maintained through the rotor (otherwise a brick wall would be a 100% efficient wind power extractor). So, we need to include some additional terms to get a practical equation for a wind turbine.

<u>Direct Torque Control Strategy [4]</u>

The basic functional blocks used to implement the DTC scheme are represented in Figure.1. The instantaneous values of the stator flux and torque are calculated from stator variable by using a closed loop estimator [1]. Stator flux and torque can be controlled directly and independently by properly selecting the inverter switching configuration.

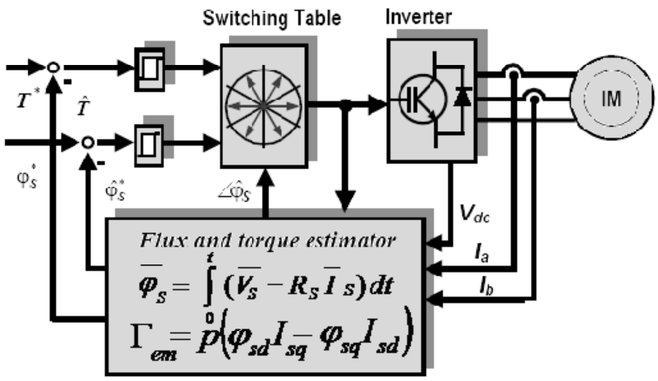
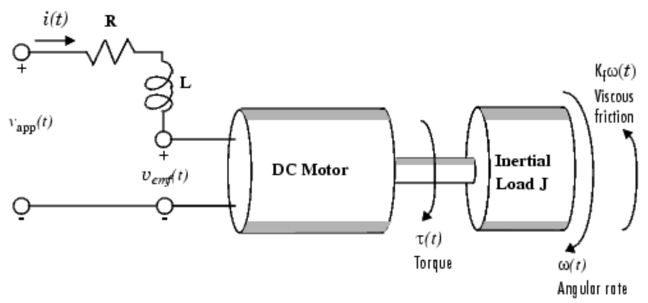


Figure 2.2: Basic direct torque control scheme for ac motor drives

DC Motor Model [5]



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The system (motor driving a load) final equations are:

$$\frac{di}{dt} = \frac{V_{app}}{L} - \frac{R}{L}i - \frac{K_\varphi}{L}\omega \quad (3)$$

$$\frac{d\omega}{dt} = \frac{K_\varphi}{J}i - \frac{b}{J}i \quad (4)$$

Where:

b → viscous friction

J → moment of inertia for the motor load

Kφ → armature or emf constant

FLYING WIND TURBINES[8]

San Diego based Sky WindPower is developing a kite-like 1,100 pound Flying Electric Generator (FEG) capable of producing power for as little as two cents per kilowatt hour and flying between 15,000 and 30,000 feet. Four rotors at the points of an H-shaped frame provide the necessary lift to keep the platform floating in the air like a kite. Electricity generated by the spinning rotors is transmitted to the ground through aluminum cables tethered to the frame.

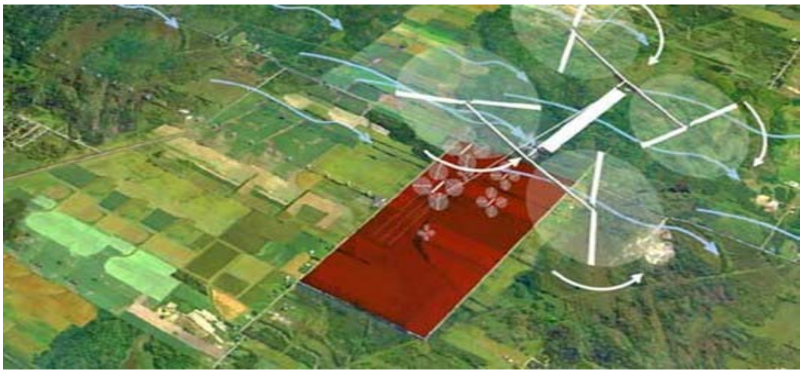


Figure 2.3: Flying Wind Turbine

RAM AIR TURBINE (RAT)[9]

A ram air turbine (RAT) is a small turbine that is connected to a hydraulic pump, or electrical generator, installed in an aircraft and used as a power source. The RAT generates power from the airstream due to the speed of the aircraft.

RATs are common in military aircraft which must be capable of surviving sudden and complete loss of power. The Airbus A380 has the largest RAT propeller in the world at 1.63 m in diameter, but around 80 cm is more common. Propellers started as two-bladed or four-bladed models but military (and increasingly commercial) models now use ducted multi-blade fans. Smaller, low airspeed models may generate as little as 400 watts.

Figure 2.4: RAT on Boeing 757 commercial airline

CleanTech Breakthrough: Wind-powered Airplanes[10]

- According to inventor Dr. Josef Popf, "The idea struck me as I was driving through a wind farm in Kentucky. Why not strap one of those puppies to an airplane? When I first started doing the math, it was really just for fun. I expected the wind turbine to slow down the airplane. But the deeper I delved into the problem, the more plausible it started to appear. Then, after about two solid months, I found the answers I needed and filed for a patent."
- Essentially, it's not so different from the hybrid systems employed by hybrid cars. As an airplane cruises or comes in to land, the turbine super-charges high-capacity batteries. That energy can then be used during future take-offs and landings.
  The trick, according to Popf, is to use the wind turbine at high altitudes, where the thinner atmosphere puts less stress on the airplane, preventing excessive drag. Then, during landing, the wind turbine helps to slow the plane, saving even more fuel. Popf estimates airlines could increase fuel efficiency by 50%-70%, depending on the craft.
- Dr. Josef Popf is a physicist better known for his work with the U.S. Navy–some of which is still top-secret. His experience with fluid dynamics helped him innovate his wind turbine design. He claims that the application of his invention is not only limited to aviation; he's working on designs for cars, buildings, boats, and even submarines.

CHAPTER 3
METHODOLOGY

3.1 Methodology

In the preliminary stage of this project, a lot of studies need to be undertaken in order to investigate all of the potential power sources for MUAV. After finalizing all of the potential energy sources, deeper study will be done to choose the perfect energy source to be used in MUAV. At this stage, we will decide whether we will be using single power source or hybrid power by combining more than one of the power sources into one system. At the end, we need to design a micro storage system that will store all the generated energies before being used.

Subsequently, a complete system needs to be designed. This system will consist of 3 main components which are the power source(s), the power storage unit and the wiring. All of those components will form a new and uninterrupted power supply system for MUAV.

Lot of elements need to be considered during the designing phase. Most importantly, the system must meet the minimum power requirement to operate the MUAV; otherwise it cannot fly at all. Analysis and some calculations need to be done so that the system can actually support the power requirement and the MUAV can fly without any power cut-off.

Finally, if all goes well, the system can be simulated so that the real testing can be done and investigate the actual power generated by the system.

A timeline is prepared for completion of this FYP by the author based on the academic schedule, FYP guideline for students and supervisor requirements. This FYP time schedule is shown in Appendix 1.

3.2 Project Flowchart

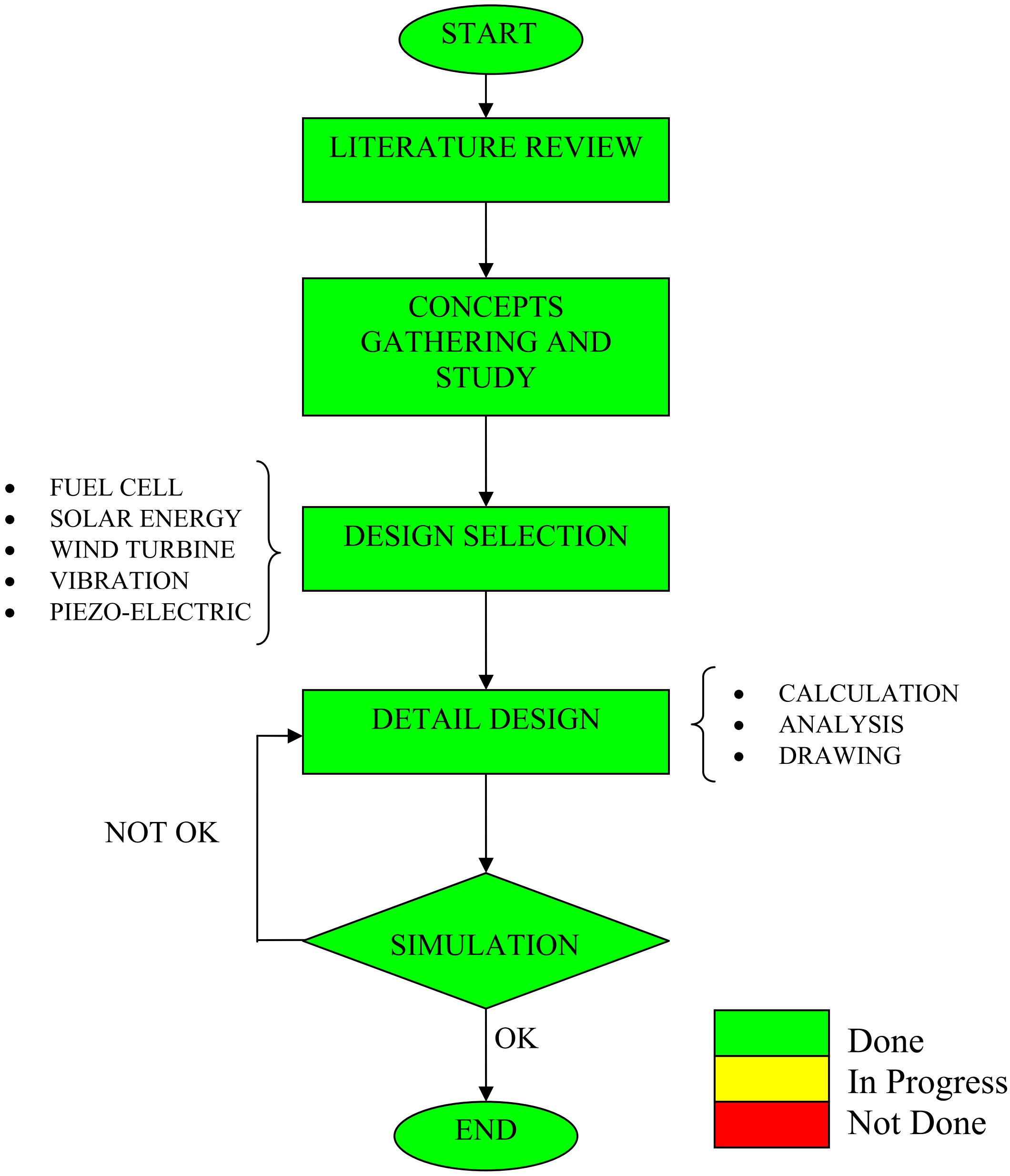


FIGURE 3.1: Project Flowchart

CHAPTER 4
DESIGN COMPARISON

4.1 Design Comparison

Based on the research that I have done, main option is the *wind turbine* which extracts energy from moving air by slowing the wind down, and transferring this harvested energy into a spinning shaft, which usually turns an alternator or generator to produce electricity. Then, I have short listed four other suitable power supplies that can be applied to the MUAV and compared with the wind turbine. First of all, the *fuel cell* which converts the chemicals hydrogen and oxygen into water and in the process it produces electricity. Then, the *solar cell* uses semiconductor to absorb the light and the energy of the absorbed light is transferred to the semiconductor to produce electricity. Next option is the *vibration concept* which converting low-frequency vibrations, like simple body movements, the beating of the heart or movement of the wind into energy. Final option is the *piezo-electric material concept* which the material's ability to transform mechanical strain into electrical charge. All those have their advantage and disadvantages if being used on the MUAV. This section will discuss and evaluate important criterion for every each of the choice to determine if there is other choice that is more suitable than wind turbine.

The criterion that being evaluated for every options are:

1. *Power Generation* – Average power that can be generated to operate the MUAV.
2. *Efficiency* – Desired energy output per energy input
3. *Maintenance* – Maintenance frequency and tendency for it to broke down.

4. *Material Availability* – Common material is more preferable in term of cost and market.
5. *Material Life* – Period before the material fails.
6. *Price* – Important for cost consideration and economics value.
7. *Reliability* - Ability of a system to perform its required functions under stated conditions for a specified period of time.
8. *Fabricability* – Measure of how easy the system to be fabricated.
9. *Size* – Important criteria since the MUAV is small, big and heavy power supply is fairly not suitable.
10. *Design Suitability* – The suitability of the system to be attached to the MUAV, considering the size and the shape.
11. *Simplicity* – Simplest design which easy to understand and producing desires power is the most preferable.

Table 4.1: Design Comparison Table

NO	CRITERIA	WEIGHT	FUEL CELL	SOLAR CELL	**WIND TURBINE**	VIBRATION	PIEZO ELECTRIC
1	Power Generation	0.15	5	2	**3**	3	3
2	Efficiency	0.10	5	3	**2**	4	4
3	Maintenance	0.05	2	4	**4**	2	2
4	Material Availability	0.10	1	4	**3**	2	1
5	Material Life	0.05	5	5	**3**	3	3
6	Price	0.05	2	4	**4**	2	2
7	Reliability	0.10	5	2	**2**	4	4
8	Fabricability	0.05	2	4	**4**	3	2
9	Size	0.10	1	4	**5**	5	5
10	Design Suitability	0.15	1	2	**5**	5	5
11	Simplicity	0.10	2	5	**5**	2	2
	TOTAL	1.00	2.85	3.25	**3.65**	3.40	3.25

4.2 Design Analysis

As for the fuel cell, it can generate the most power compared to other options but the size of a fuel cell is big and it's heavy. It is commonly used in the larger UAV and not suitable for Micro UAV.

Next, the solar cell is not suitable in this project because it needs a large area to install the solar panels to generate enough power for the MUAV. The panels are also quite heavy and it will affect the performance of the MUAV.

The vibration and piezo-electric concepts are almost the same case. Both are very suitable to be installed and attached to the MUAV, but both systems required exotic materials which will be very costly and hard to fabricate.

Finally, wind turbine is the most suitable design to be used on MUAV. It is a simple design with simple principle, easy to fabricate, low cost and can generate enough power to operate the MUAV if certain condition is achieve. The most important condition for wind turbine is the wind speed which will directly affect the power generation of the wind turbine.

CHAPTER 5
CONCEPT DESIGN

5.1 Micro Unmanned Aerial Vehicle (MUAV) Design

This is the Micro Unmanned Aerial Vehicle (MUAV) which was designed by previous mechanical student as his Final Year Project. This project is the continuation of respective project, which focuses on the micro wind turbine as the power supply for the MUAV. Figure 5.1 and 5.2 shows the basic design of the MUAV. It is mainly consists of the T-shape chassis and 4 fans at the tip of every corners. Those 4 fans will control the movement of the MUAV with a control system. Figure 5.3 shows the position of the micro wind turbine to be installed to the MUAV. The micro wind turbine is attached at the bottom of the MUAV so that the wind will pass through it and charged the battery.

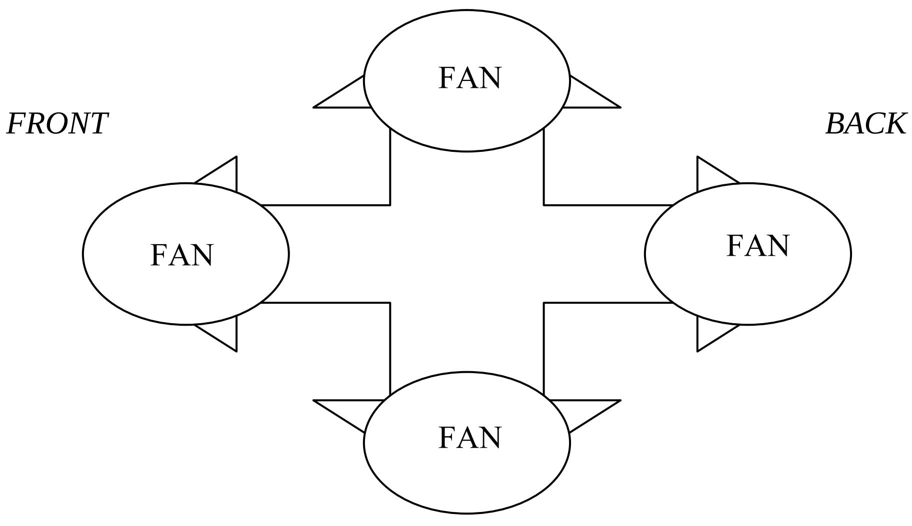


FIGURE 5.1: Plan View of the MUAV

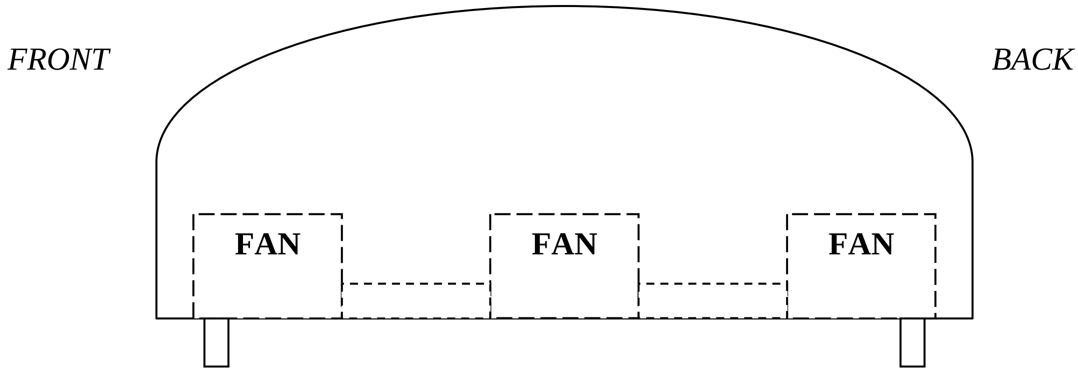


FIGURE 5.2: Side View of the MUAV

5.2 MUAV and Wind Turbine Design (Location)

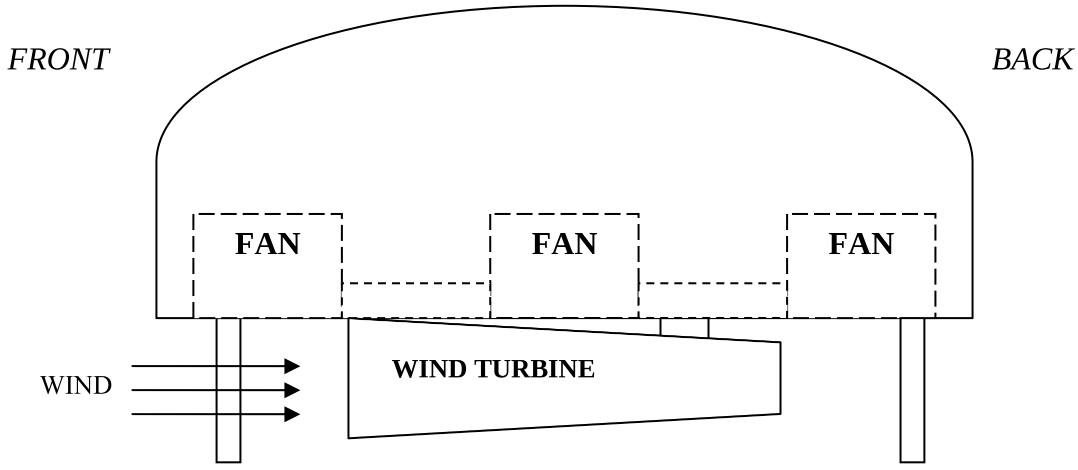


FIGURE 5.3: Wind Turbine Design 1

CHAPTER 6
DETAIL DESIGN

6.1 Alternator Detail Design

ALTERNATOR DESIGN CONSIDERATIONS

A. Maximum Power Output
B. Minimum Torque

A. Maximum Power Output

The micro wind turbine must be designed so that it can supply enough power to charge the Lithium battery used for the MUAV. The MUAV is operated by 4 fans which are driven by 4 Precision Motors. The power requirements are as below:

1 Motor Power Requirement: 252mW (0.252W)
4 Motor Power Requirement: 4 x 0.252 = 1.00 W
50% Contingency = 1.50 W

B. Minimum Torque

Every alternator or generator requires a minimum torque before it will operate.

$$BHP = \frac{(2\pi r)(F)(n)}{33000\ ft-lb/\min} = \frac{2\pi nT}{33000} \qquad (5)$$

Where:

n = revolution per minute (rpm)
T = torque (ft-lb)

Based on that Horsepower formula, we can derive into this:

$$T = \frac{33000(BHP)}{2\pi n} \qquad (6)$$

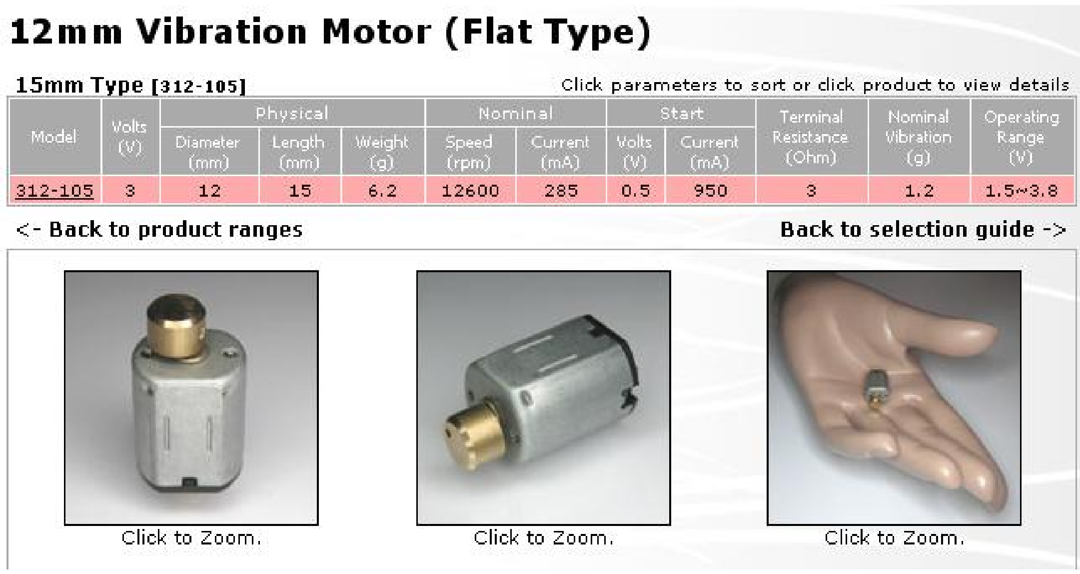
Thus;

$$BHP = \frac{1hp}{746W} \times 1.50W = 0.00201hp$$

$$n = 500rpm$$

Then we get the torque value; T = **0.00211 ft-lb (0.00286N.m)**

ALTERNATOR SUGGESTION


12mm Vibration Motor (Flat Type)

15mm Type [312-105] Click parameters to sort or click product to view details

Model	Volts (V)	Physical			Nominal		Start		Terminal Resistance (Ohm)	Nominal Vibration (g)	Operating Range (V)
		Diameter (mm)	Length (mm)	Weight (g)	Speed (rpm)	Current (mA)	Volts (V)	Current (mA)			
312-105	3	12	15	6.2	12600	285	0.5	950	3	1.2	1.5~3.8

Figure 6.1 : 12mm Precision Microdrives[5]

6.2 Fan Detail Design

FAN DESIGN CONSIDERATIONS

A. Number of Blades [3 blades]
B. Rotor Solidity
C. Tip Speed Ratio
D. Blade Pitch [5^0]
E. Blade Profile

Blade Profile

Method of evaluating the best blade profile:

1. Select 3 types of basic wind turbine blade profile, NACA 4417, NACA 4424 and NACA 4419.
2. Design the blade profile in CATIA V5 with precise dimensions.
3. Mesh the blades design in GAMBIT.
4. Flow analysis in FLUENT, find the velocity profile for respective blades profile.
5. Calculating the lift coefficient for each blades profile using online software from National Aeronautics and Space Administration (NASA).
6. Based on the collected data; the lift force for respective blades profile were calculated and compared. Corresponding formula used to calculate lift force was:

   $$F_L = \frac{v^2}{2} C_L \rho A$$

7. Torques for each blades profile was calculated based on the lift force.
8. Blade profile with highest lift force and torque was selected.

Blade Profile 1 (NACA 4417)

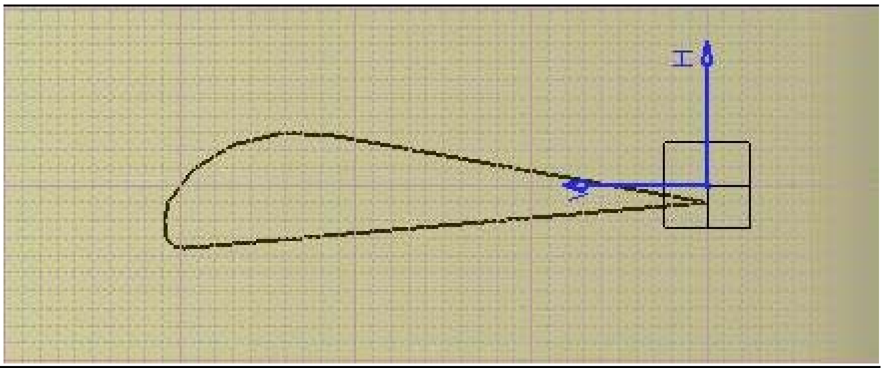


Figure 6.2 : NACA 4417 Blade Geometry

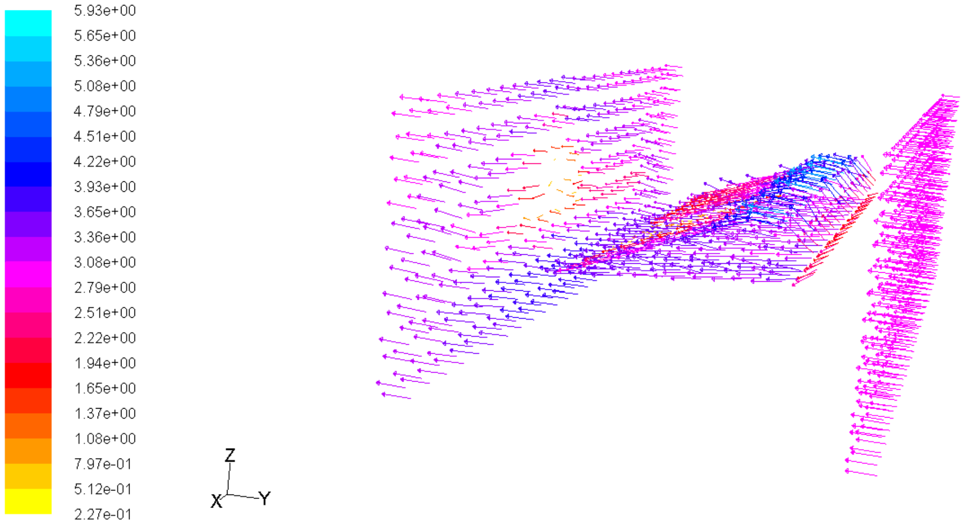


Figure 6.3 : NACA 4417 Velocity Profile from FLUENT

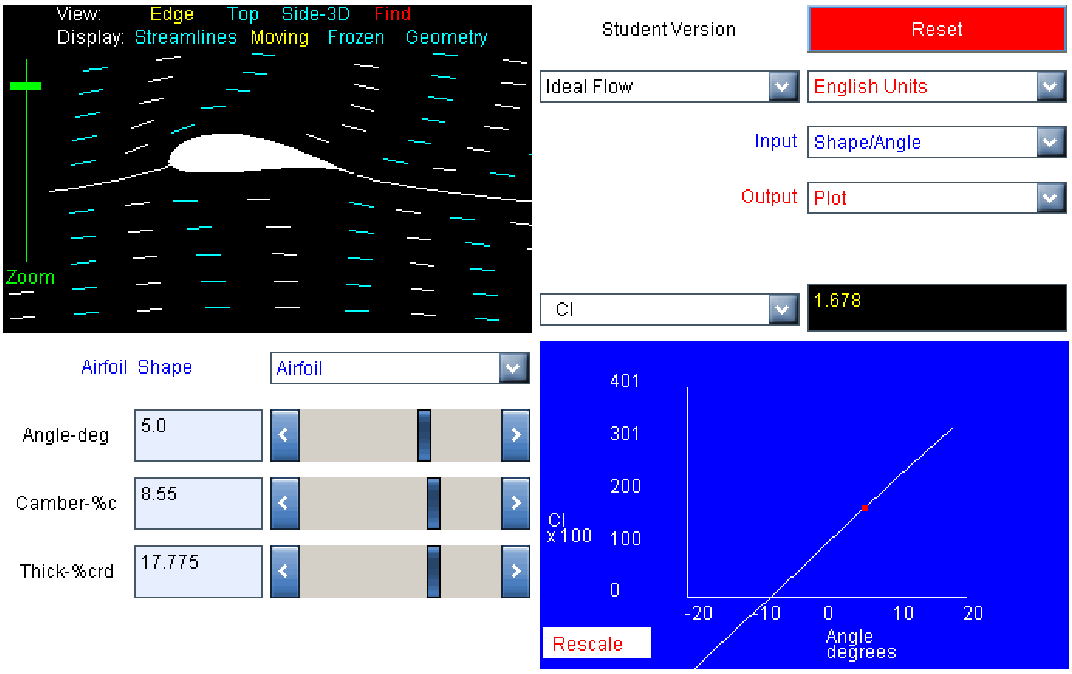


Figure 6.4 : NACA 4417 Flow Data from SimFoil II

$$F_L = \frac{v^2}{2} C_L \rho A \qquad (7)$$

Based from FLUENT data; at 5^0, v = 5.93 m/s

Based from SimFoil II data; at 5^0, C_L = 1.678

A = 0.05 x 0.04 = $0.002m^2$

$$F_L = \frac{5.93^2}{2}(1.678)(1.23)(0.002) = 0.0726N$$

Torque Produced, T = 0.0726 x 0.04 = 0.0029 N.m

Blade Profile 2 (NACA 4424)

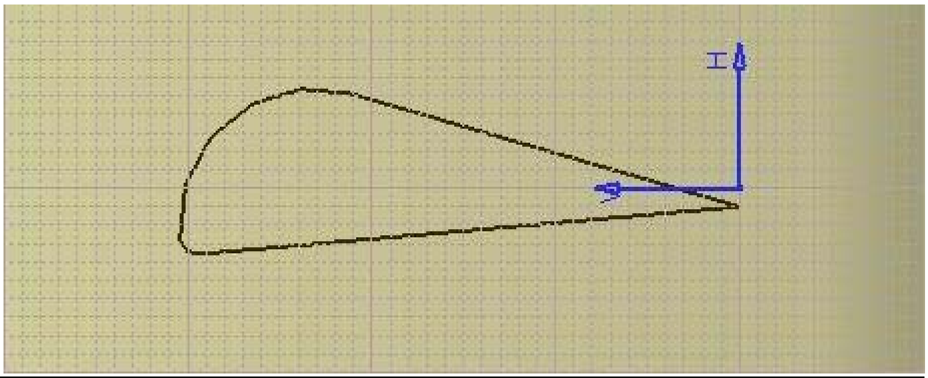


Figure 6.5 : NACA 4424 Blade Geometry

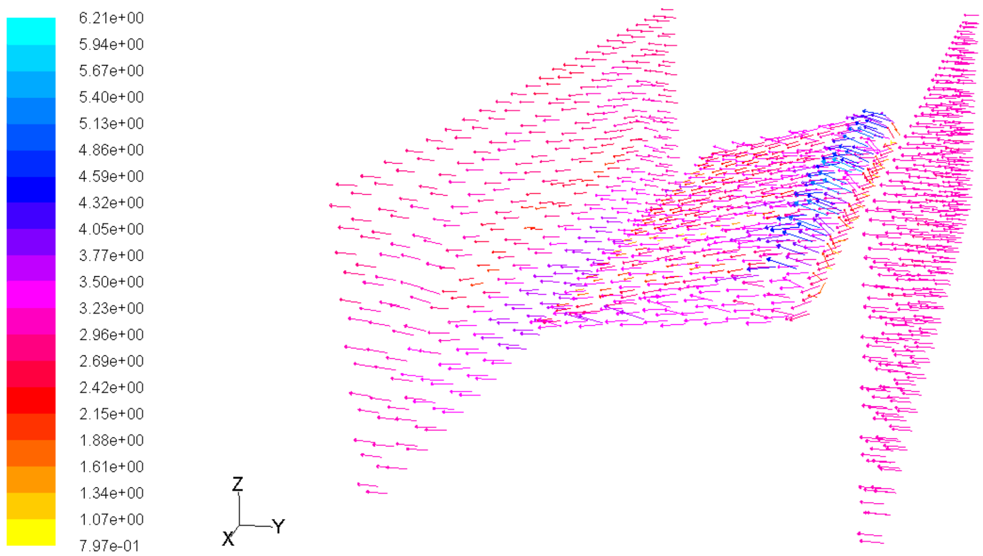


Figure 6.6 : NACA 4424 Velocity Profile from FLUENT

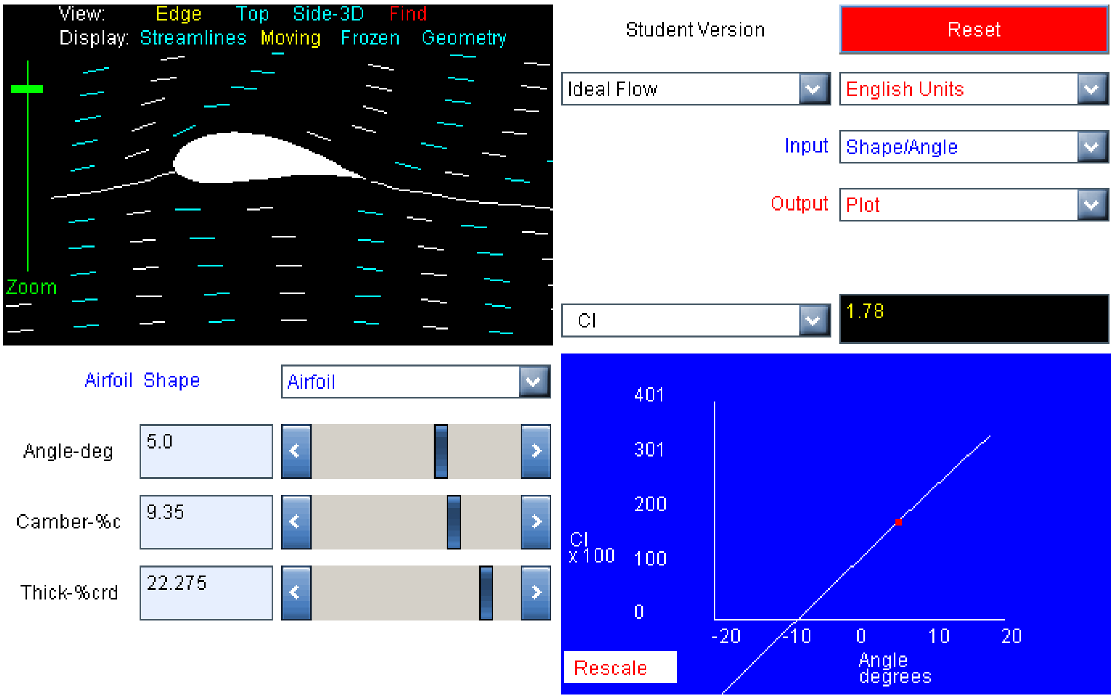


Figure 6.7 : NACA 4424 Flow Data from SimFoil II

$$F_L = \frac{v^2}{2} C_L \rho A$$

Based from FLUENT data; at 5^0, v = 6.21 m/s

Based from SimFoil II data; at 5^0, C_L = 1. 780

A = 0.05 x 0.04 = 0.002m^2

$$F_L = \frac{6.21^2}{2}(1.78)(1.23)(0.002) = 0.0844N$$

Torque Produced, T = 0.0844 x 0.04 = 0.0034 N.m

Blade Profile 3 (NACA 4419)

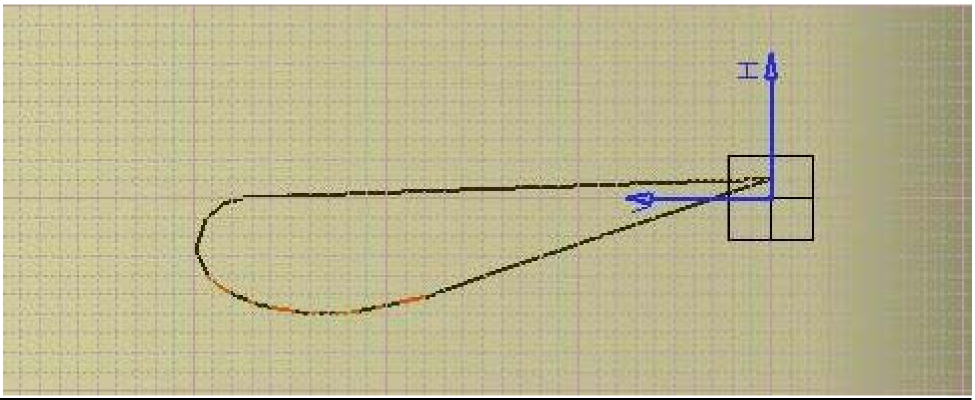


Figure 6.8: NACA 4419 Blade Geometry

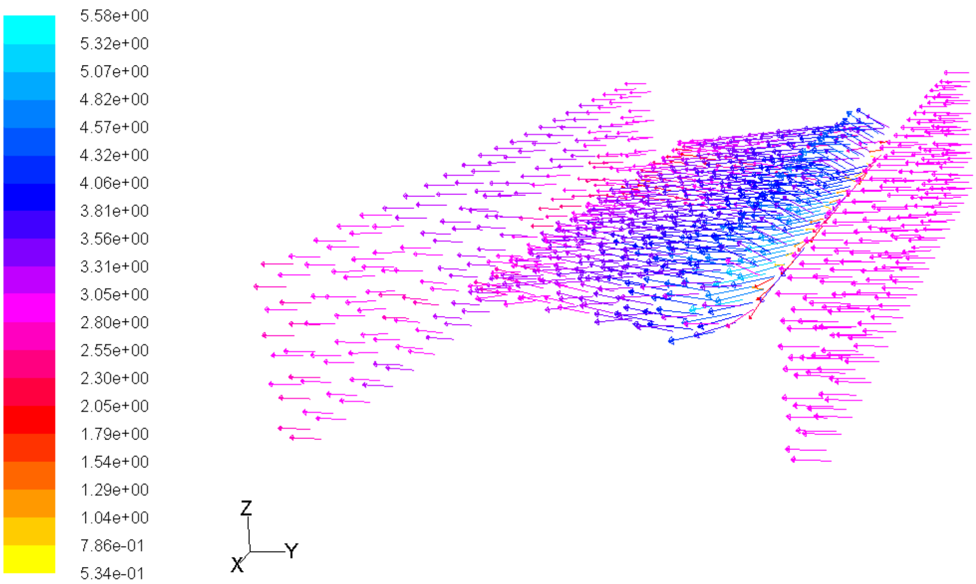


Figure 6.9 : NACA 4419 Velocity Profile from FLUENT

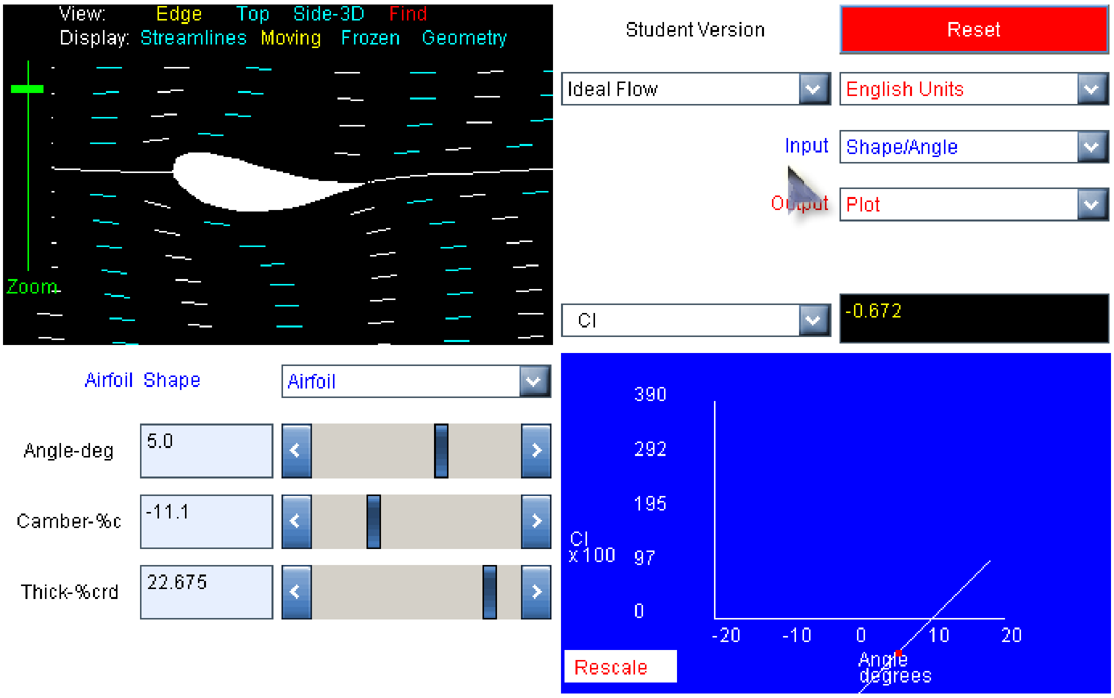


Figure 6.10 : NACA 4419 Flow Data from SimFoil II

$$F_L = \frac{v^2}{2} C_L \rho A$$

Based from FLUENT data; at 5^0, v = 5.58 m/s

Based from SimFoil II data; at 5^0, C_L = -0.672

A = 0.05 x 0.04 = 0.002m^2

$$F_L = \frac{5.58^2}{2}(-0.672)(1.23)(0.002) = -0.0257N$$

Torque Produced, T = -0.0257 x 0.04 = -0.0011 N.m

Final Design

Table 6.1 : Blade Profile Comparison

BLADE PROFILE	LIFT FORCE (N)	TORQUE (N.m)
NACA 4417	0.0726	0.029
NACA 4424	0.0844	0.0034
NACA 4419	-0.0257	-0.0011

Blade Pitch = 5^0

Num Of Blades = 3

Blade Geometry = NACA 4424

Torque Produced, T = 0.0844 x 0.04 = 0.0034 N.m

Alternator = 1.50 W

Minimum Torque = 0.00286 N.m

CATIA DESIGN

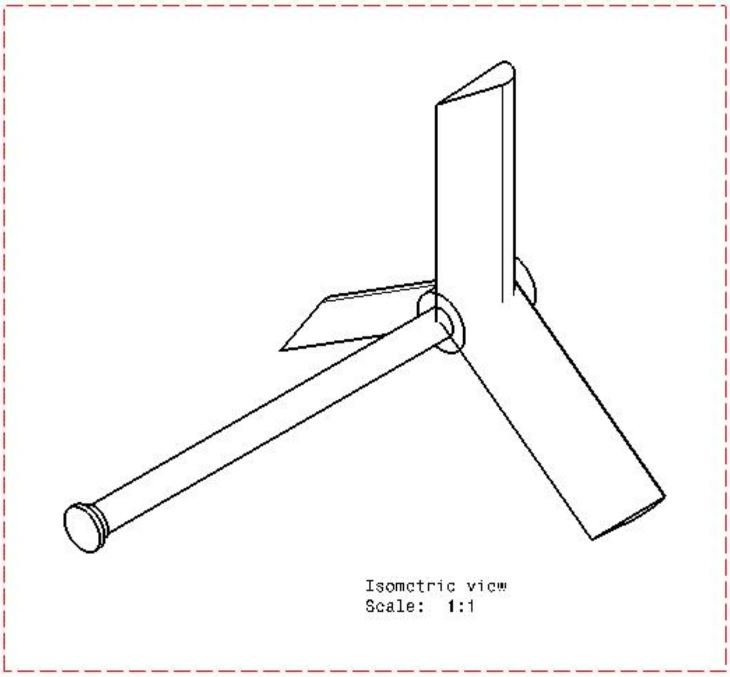


Figure 6.11 : Fan Design for Micro Wind Turbine

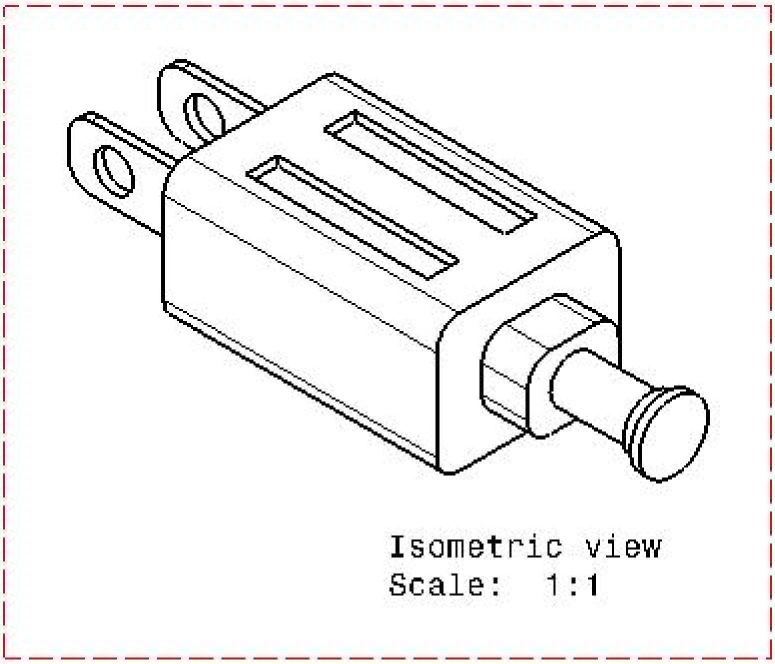


Figure 6.12: Motor Design for Micro Wind Turbine

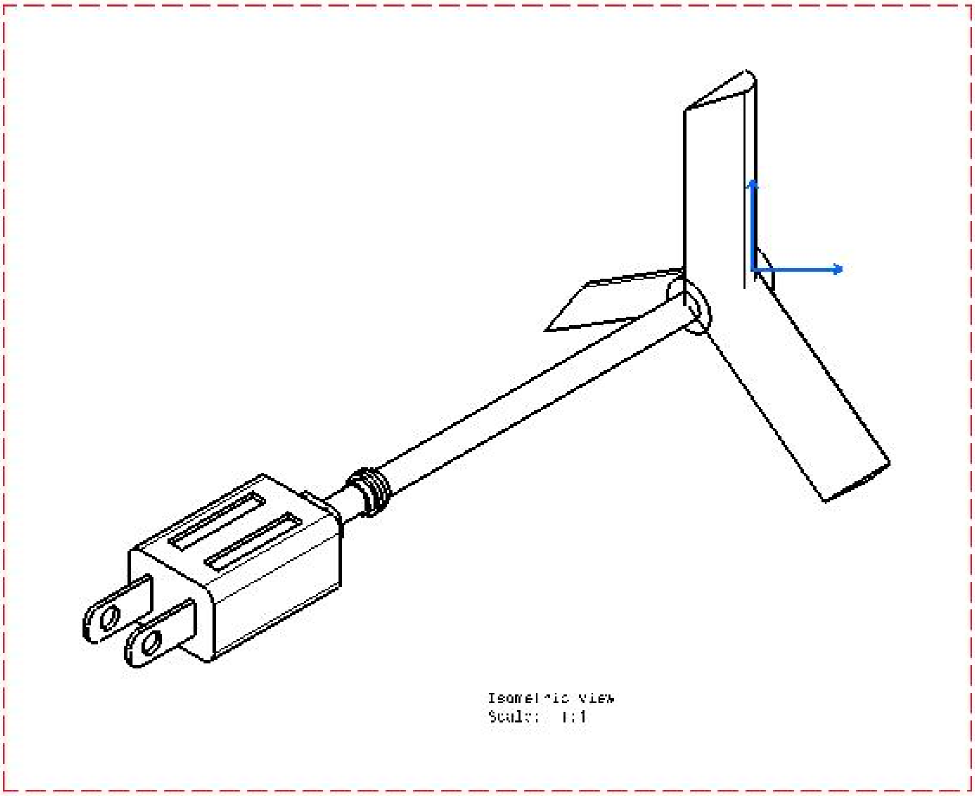


Figure 6.13 : Assembly Design for Micro Wind Turbine

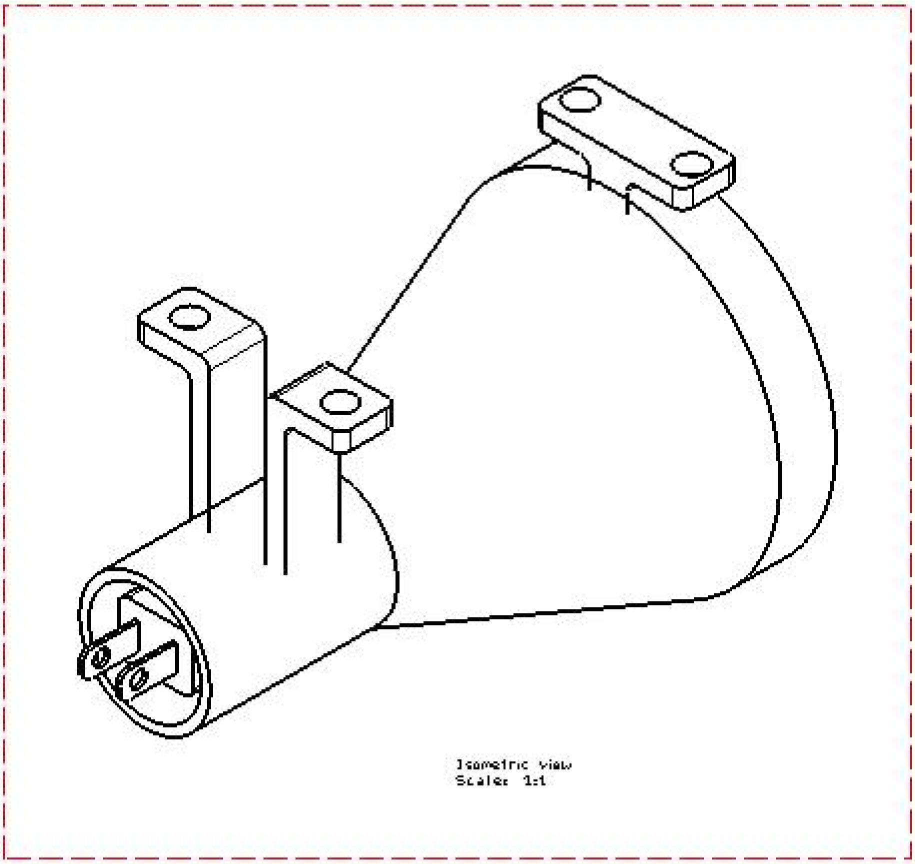


Figure 6.14 : Assembly Design for Micro Wind Turbine with Casing

CHAPTER 7
ANALYSIS AND SIMULATION

7.1 Modeling and Simulating Micro Wind Turbine Control System

Assumption 1: The gap air flux is proportional to the field current.

$\Phi \propto i_f \quad \rightarrow \quad \Phi = k_1 i_f$

Assumption 2: The torque developed on the motor shafts is proportional to the product of armature current and the air gap flux.

$\tau \propto \Phi \mathrm{i}_\alpha \quad \rightarrow \quad \tau = k_2 \Phi \mathrm{i}_\alpha = k_1 k_2 \mathrm{i}_\alpha \mathrm{i}_f$

Assumption 3: The voltage generated is proportional to the velocity of turbine shaft.

$v_g \propto \dot{\theta}_t$

<u>Mechanical Turbine Part</u>

$$\tau_t = J_t \frac{d^2\theta_t}{dt^2} + D_t \frac{d\theta_t}{dt} + \tau_g \qquad (8)$$

As in Laplace:

$$T_t(s) = J_t s^2 \theta_t + D_t s \theta_t + \tau_g(s) = [J_t s^2 + D_t s]\, \theta_t + T_g(s) \qquad (9)$$

<u>Electro-Mechanical Part</u>

Relationship between the torque and the armature current

$$\tau = k_1 k_2 \mathrm{i}_\alpha \mathrm{i}_f \quad \rightarrow \quad \mathrm{T_g}(s) = k_s I_\alpha(s) \qquad (10)$$

Relationship between generated voltage and angular speed

$$v_g \propto \dot{\theta}_t \quad \rightarrow \quad v_g = k_r \dot{\theta}_t \quad \rightarrow \quad V_g(s) = k_r s \theta_t \qquad (11)$$

Electrical Part

By applying Kirchoff's Voltage Law (KVL), we obtain:

$$v_g = L_\alpha \frac{di_\alpha}{dt} + R_\alpha i_\alpha \qquad (12)$$

As In Laplace:

$$V_g(s) = (L_\alpha s + R_\alpha) I_\alpha(s) \qquad (13)$$

Thus, the equation:

$$\theta_t(s) = \frac{1}{J_t s^2 + D_t s}[T_t(s) - T_g(s)] \qquad \text{---(1)}$$

$$V_g(s) = k_r s \theta_t \qquad \text{---(2)}$$

$$I_\alpha(s) = \frac{1}{L_\alpha s + R_\alpha}[V_g(s)] \qquad \text{---(3)}$$

$$\mathrm{T_g}(s) = k_s I_\alpha(s) \qquad \text{---(4)}$$

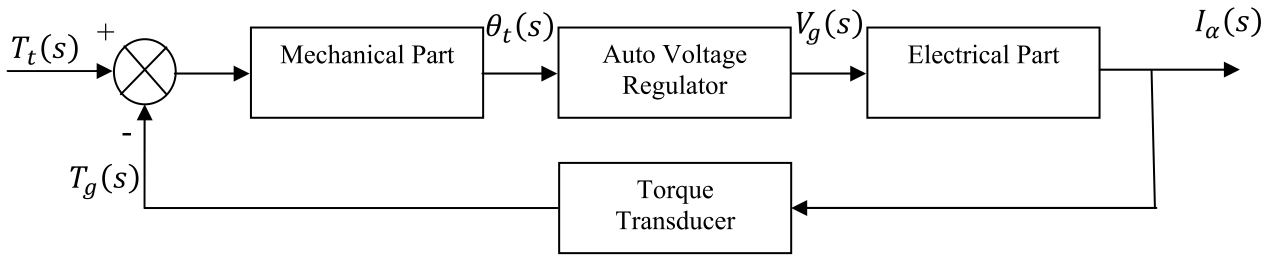


Figure 7.2: Basic Block Diagram of Micro Wind Turbine Control System

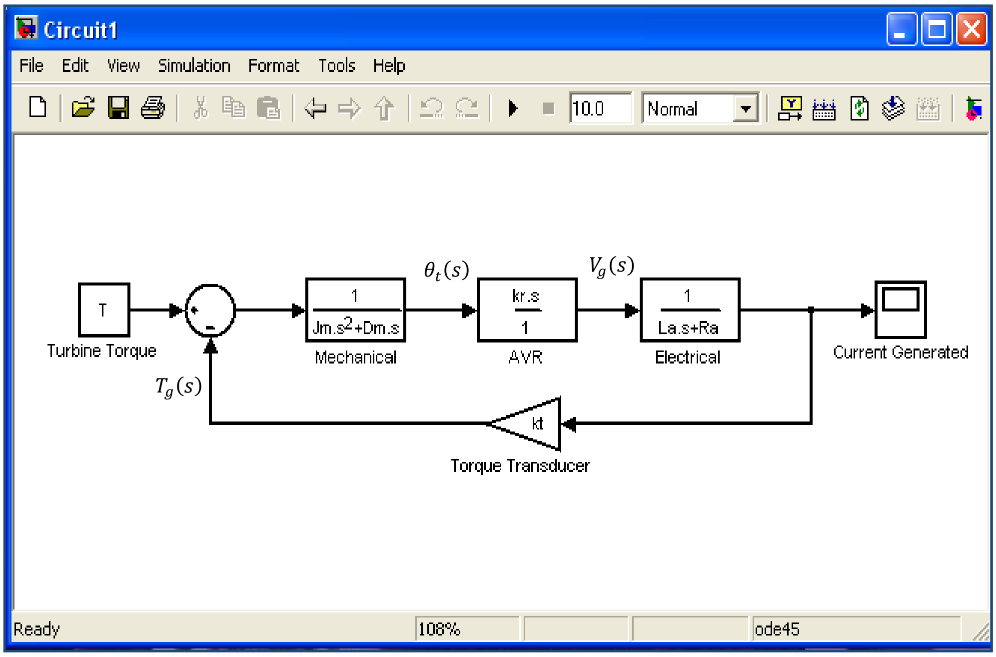


Figure 7.3: Block Diagram in MATLAB Simulink

7.2 Results

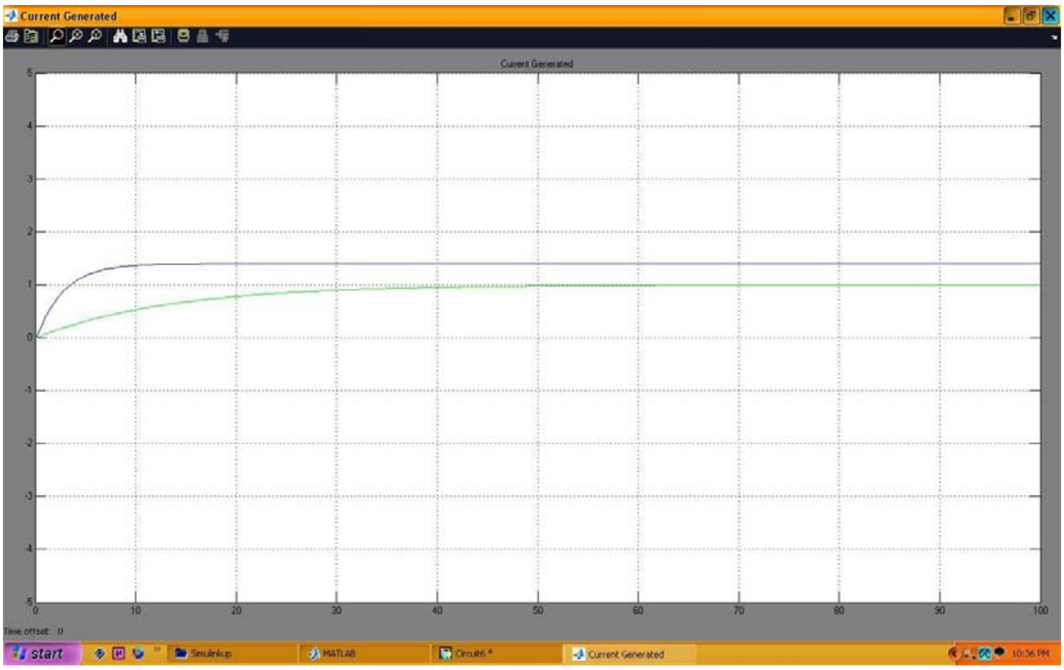


Figure 7.4: Power Consumption and Generated for the MUAV during flight

GUIDE:
-Power Consumed
-Power Generated

7.3 Result Discussion

Based on Figure 7.4, we can see that the power consumed to fly the MUAV is greater than the power generated by the wind turbine. This happens because of the high induced energy need to be used to lift the MUAV due to the weight and minimal downward drag. Other than that, during the flight of the MUAV, wind turbine also cannot sustain the maximum power required to fly the MUAV due to the high drag force exerted on the MUAV. This will make the MUAV need more power to move than the power supplied by the wind turbine. This is also been said as the *3rd Perpetual Motion Kind* which completely eliminates friction and other dissipative forces, to maintain motion forever (due to its mass inertia).

Nevertheless, this power system is not solely supported by a wind turbine itself; their main power supplies are two *Saft LST14250 Li-SOCl^2 Lithium Battery Cell*. Thus, the wind turbine will only functioned to recharge the battery and increase the lifetime of the battery and consequently increase the flight time of the MUAV. Below is the calculated flight time of the MUAV referring to the simulation result.

<u>BATTERY : 2 units Saft LST14250 Li-SOCl^2 Lithium Battery Cell</u>

Voltage = 7.4 V

Capacity = 2100 mAh

Figure 7.5: Saft LST14250 Li-SOCl^2 Lithium Battery Cell

<u>MUAV</u>

Consumption = 1.0 Wh

Normal Battery lifetime

$$t = Voltage \times \frac{Batt\ Capacity}{Power\ Consumption} \quad (14)$$

$$t = 7.4V \times \frac{1.2Ah}{1.0Wh} = \mathbf{8.9hours}$$

Battery lifetime after micro wind turbine installation

Based on the simulation; we can estimate the power consumption of MUAV after WT installation:

$$Power\ Consumption = 1.0Wh \times \frac{1.0Wh}{1.4Wh} = 0.714Wh$$

$$t = 7.4V \times \frac{1.20Ah}{0.714Wh} = \mathbf{12.43hours}$$

Thus, the installation of wind turbine will increase the lifetime of battery for about **40%**.

CHAPTER 8
CONCLUSION AND RECOMMENDATION

8.1 Conclusion

The aimed to design a micro wind turbine system to operate the MUAV was achieved. The goal is to develop a good system that can be further improved in the future since there is not much research being done in using wind turbine as MUAV power supply.

The system consists of 2 main power sources which are the *Lithium battery* and the *Micro Wind Turbine* to recharge the battery during the flight. The battery that has been selected to be used for the MUAV are two units of *Saft LST14250 Li-SOCl*^{2} *Lithium Battery Cell* due to its size, voltage and capacity which are suitable to sustain the MUAV flight. It only weight 37 grams with 7.4V of voltage and 1200 mAh of current capacity. This battery is selected by the designer of the MUAV himself. As for the Micro Wind Turbine, many factors have been investigated to design it so that it can generate the most power to charge the battery. Softwares used to design and analyze the Micro Wind Turbine are *CATIA V5, GAMBIT, FLUENT* and *SimFoil II*. Below are the final design descriptions of the Micro Wind Turbine:

Blade Pitch = 5^0

Num Of Blades = 3

Blade Geometry = NACA 4424

Torque Produced, T = 0.0034 N.m

Alternator = 1.50 W

Minimum Torque = 0.00286 N.m

Simulation of the Micro Wind Turbine System is done using MATLAB Simulink to investigate how much power consumed by the MUAV and maximum power that can be generated by the Micro Wind Turbine. The system was designed by *reversing the DC Motor basic system* to be used for Micro Wind Turbine system simulation. The result shows that the MUAV can fly for *8.9 hours* without the micro wind turbine. Nevertheless, with the addition of micro wind turbine, the MUAV can fly for about *12.43 hours*. Thus, the installation of wind turbine will increase the lifetime of battery for about **40%**.

It can be concluded that the design of Micro Wind Turbine can increase the battery life and consequently increase the flight time of the MUAV. This will make the MUAV more efficient and more work can be done by it. Since this is a new design, more improvement can be done to make this system more reliable.

8.2 Recommendation

1. The design of the wind turbine can still be improved by varying and experimenting on its *number of blade, rotor solidity, tip speed ratio, pitch angle and even the blade profile*. All of those factors are the main components that affect the wind turbine performance.
2. There are other potential power sources that can be extracted during the flight of the MUAV such as the vibration of MUAV. There are some ways we can extract that energy; in example by using the *piezo-electric principle* that generates electricity by kinetic energy. This method need a lot of understanding on the principle and the piezo-electric material is also difficult to purchase.
3. Since the job scope of this study restricted to design a system for specific MUAV, there is nothing can be done to the MUAV itself in order to improve the system performance. A *glider* can be installed to the MUAV so that when the battery power is off, the glider will allow the MUAV to just glide in the air while the wind turbine extract the wind energy and recharge the battery without consuming any energy.

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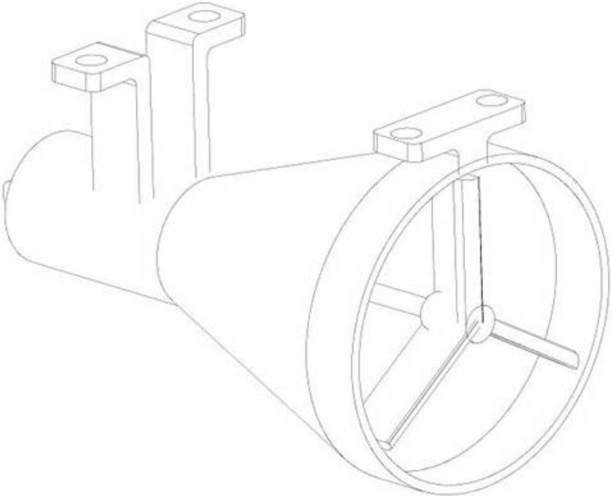
APPENDIX 1

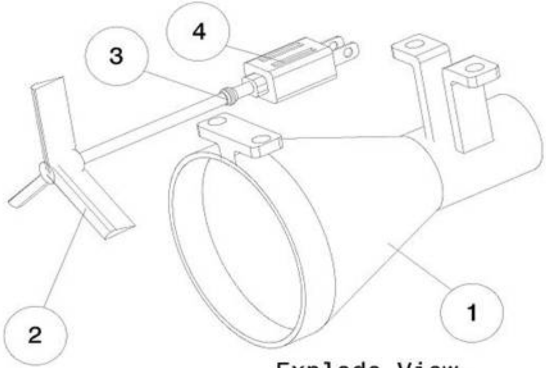
FYP GANTT CHART

APPENDIX 2

MICRO WIND TURBINE DETAIL DESIGN



Isometric view



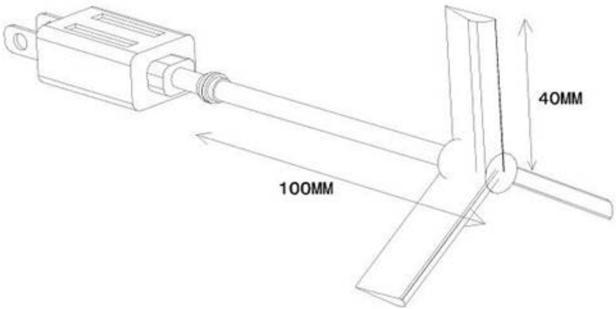
Explode View

ITEM	QTY	NAME
1	1	CASING
2	1	FAN/TURBINE
3	2	COUPLING
4	1	PRECISION MICRODRIVES

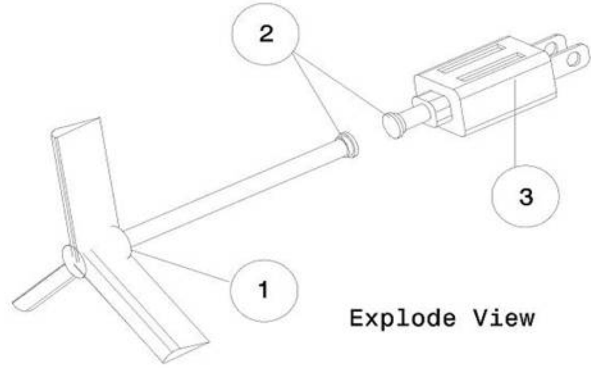
MICRO WIND TURBINE ASSEMBLY DESIGN WITH CASING

MOHD ALIFF OMAR BIN HARIS

MECHANICAL ENGINEERING	9321



Isometric View



Explode View

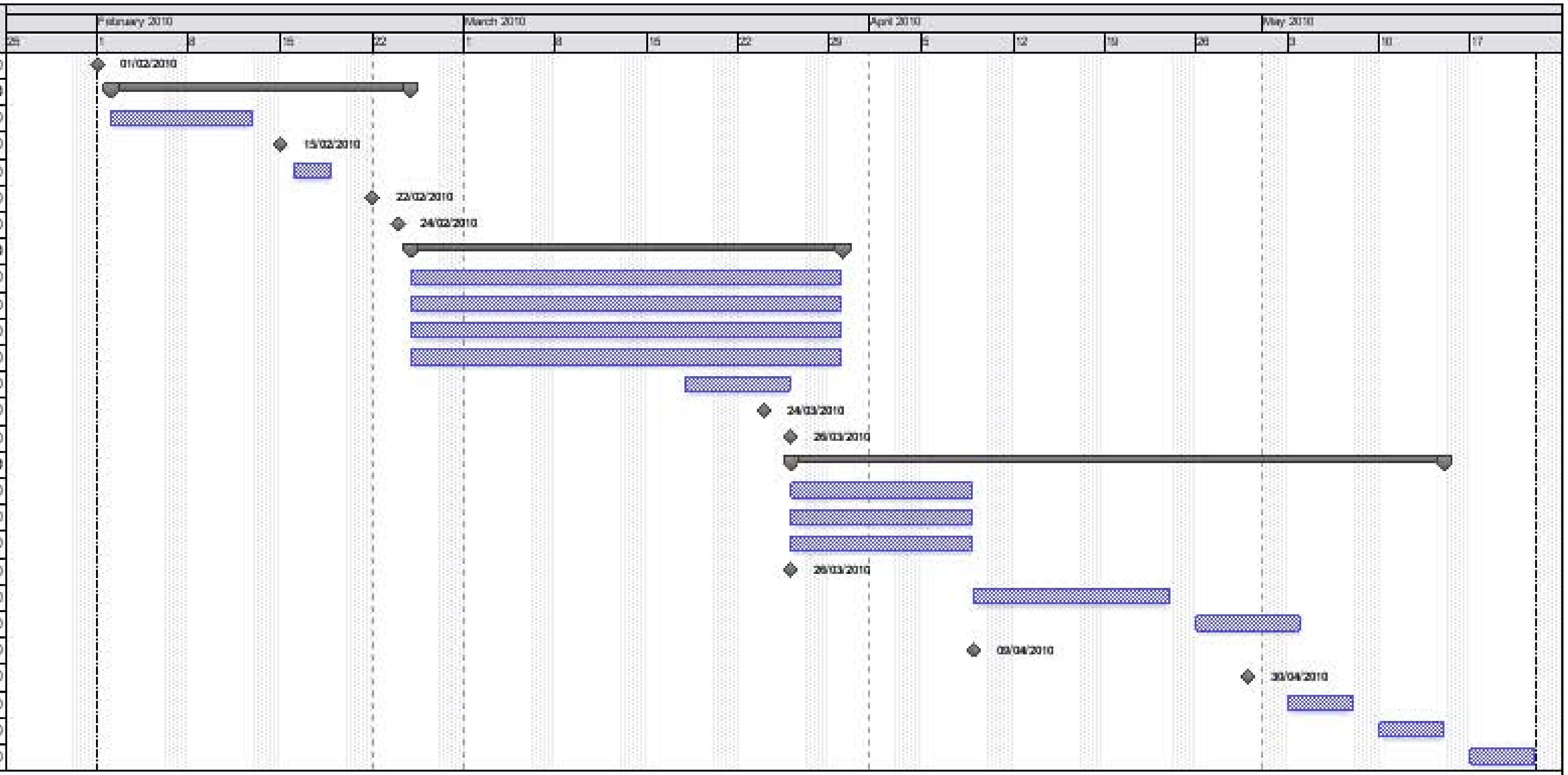
ITEM	QTY	NAME
1	1	FAN/TURBINE
2	2	COUPLING
3	1	PRECISION MICRODRIVES

MICRO WIND TURBINE ASSEMBLY DESIGN WITHOUT CASING

MOHD ALIFF OMAR BIN HARIS

MECHANICAL ENGINEERING | 9321

ID	Task name	Length	Start	Finish
1	Project Title Award and Confirmation	1 d	01/02/2010	01/02/2010
2	**Preliminary Research Work**	**17 d**	**02/02/2010**	**24/02/2010**
3	Literature Review	9 d	02/02/2010	12/02/2010
4	Methodology Selection	1 d	15/02/2010	15/02/2010
5	Preliminary Report Writing	3 d	16/02/2010	18/02/2010
6	Submission Of Prelim Report (Draft)	1 d	22/02/2010	22/02/2010
7	Submission Of Prelim Report (Finalize)	1 d	24/02/2010	24/02/2010
8	**Project Work**	**23 d**	**25/02/2010**	**29/03/2010**
9	Micro Power Alternative Sources Study	23 d	25/02/2010	29/03/2010
10	MUAV Power Requirement Study	23 d	25/02/2010	29/03/2010
11	Generated Power Storage System	23 d	25/02/2010	29/03/2010
12	Hybrid System Study	23 d	25/02/2010	29/03/2010
13	Progress Report Writing	6 d	18/03/2010	25/03/2010
14	Submission Of Progress Report (Draft)	1 d	24/03/2010	24/03/2010
15	Submission Of Progress Report (Finaliz	1 d	26/03/2010	26/03/2010
16	**Continuation of Project Work**	**36 d**	**26/03/2010**	**14/05/2010**
17	Study on Data Collected	10 d	26/03/2010	08/04/2010
18	Review on Related Subject	10 d	26/03/2010	08/04/2010
19	Designing MUAV Power System	10 d	26/03/2010	08/04/2010
20	Seminar	1 d	26/03/2010	26/03/2010
21	Analysis and Simulation of the MUAV Po	11 d	09/04/2010	23/04/2010
22	Interim Report Writing	6 d	26/04/2010	03/05/2010
23	Submission Of Interim Report (Draft)	1 d	09/04/2010	09/04/2010
24	Submission Of Interim Report (Finalize)	1 d	30/04/2010	30/04/2010
25	Preparation for Oral Presentation	5 d	03/05/2010	07/05/2010
26	Oral Presentation	5 d	10/05/2010	14/05/2010
27	Submission of Final Report	5 d	17/05/2010	21/05/2010



No	Activity	Start	End	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
1	Planning	26-Jul	30-Jul														
2	Energy Balance Analysis	2-Aug	13-Aug														
3	MATLAB Simulink Familiarization	16-Aug	20-Aug														
4	Progress Report 1	20-Aug					o										
5	MATLAB Simulink Simulation	23-Aug	3-Sep														
6	Mid Term Break	6-Sep	10-Sep														
7	Continue Simulink Simulation	13-Sep	17-Sep														
8	Progress Report 2 And Seminar	20-Sep	24-Sep														
9	Analyze And Finalize Results	27-Sep	1-Oct														
10	Poster Preparation and Presentation	4-Oct	15-Oct														
11	Final Desertation Preparation	18-Oct	29-Oct														
12	Submission of Final Dessertation	1-Nov	5-Nov														
13	Hardbound	5-Nov															o