CONCEPTUAL DESIGN OF MINI WIND TURBINE FOR HOUSEHOLD APPLICATION

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ABSTRACT

Wind turbine is a device that using the renewable energy to produce electrical power. It converts the wind energy to become electricity by rotating the rotor blade. In international or domestic market, small size wind turbines normally have their market value which can produce electricity for household application. Hence, the purpose of this project is to design a mini size wind turbine which able to use it for household application. Through this project, case study on current trend of small size wind turbine is carried on. Three conceptual design of mini size wind turbine are proposed with power generation analysis using CFD software. Material selection and Finite Element analysis are conducted to determine the best material for it. Cost estimation and weight calculation are done to determine the feasibility of making the designed product.

ABSTRAK

Turbin angin adalah alat yang menggunakan tenaga boleh diperbaharui untuk menghasilkan kuasa elektrik. Ia menukarkan tenaga angin untuk menjadi tenaga elektrik oleh putaran bilah pemutar. Dalam pasaran antarabangsa atau domestik, turbin angin saiz kecil biasanya mempunyai nilai pasaran mereka yang boleh menghasilkan tenaga elektrik untuk permohonan rumah. Oleh itu , tujuan projek ini adalah untuk membentuk turbin angin saiz mini yang dapat menggunakannya untuk aplikasi rumah. Bersama-sama projek ini, kajian kes kepada trend semasa turbin angin kecil saiz dijalankan. Tiga reka bentuk konsep turbin angin saiz mini dicadangkan dengan analisis penjanaan kuasa menggunakan perisian CFD. Pemilihan bahan dan FEA analisi dijalankan untuk memilih bahan yang terbaik untuk itu. Anggaran kos dan pengiraan berat juga dijalankan untuk menentukan kemungkinan membuat produk yang direka.

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LIST OF SYMBOL

W	=	Watt
v	=	volume
V	=	Velocity
L	=	Length
p	=	density
F_D	=	Drag Force
F_L	=	Lift Force
L_f	=	Lift coefficient
L_D	=	Drag coefficient
Pa	=	Pascal
s	=	second
C_p	=	power coefficient
P	=	Power
A	=	Area
λ	=	tip speed ratio
ω_m	=	rotational speed
R	=	radius

LIST OF ABBEREVATIONS

WT	Wind Turbine
HWAT	Horizontal Axis Wind Turbine
VAWT	Vertical Axis Wind Turbine
RE	Renewable Energy
MWT	Mini Wind Turbine
CFD	Computational Fluid Dynamic
DC	Direct Current
NACA	National Advisory Committee for Aeronautics
FEA	Finite Element Analysis

CHAPTER 1

INTRODUCTION

1.1 Background

Wind energy is a kind of renewable and sustainable energy that produced by natural phenomena. The Earth is surrounded by atmospheric air which not only protect us from ultraviolet solar light but also forming a flowing air motion in the Earth. Wind is formed when there is a changes in pressure and temperature of air. Thus, the kinetic motion of air form wind energy which can be changed to other form of energy, either mechanical energy or electrical energy. The wind power device that used to produce electricity is normally called as wind turbine.

Generally, wind turbines are classified as two different kinds. A turbine with a shaft mounted normally to ground is known as vertical axis wind turbine (VAWT) while turbine mounted horizontally parallel to ground is called as horizontal axis wind turbine (HAWT). VAWT can be attributed as low tip speed ratio and difficulty in controlling rotor speed, but it still has the market requirement as it can operate without additional mechanism to face the wind and generator can be installed on ground. On the other hand, HAWT designs become the mainstream development because it has better rotor control through pitch and yaw adjustment. (Schubel, 2012)

Unfortunately, although the wind turbines produce electricity by using clean energy, but it has its limitation. Large scale wind system plants mostly being built far away from urban area because they require large area for installation, noise problem and high cost. Thus, mini wind turbines are starting to be built in the country or house that near to shore area.

These turbines can operate under low wind speed, producing small amount of electricity which can provide for small household electrical device. (Kekezoglu, 2015)

1.2 Problem Statement

In recent years, Malaysia’s government has attempted to develop renewable energy (RE) in order to reduce the consumption of non-renewable energy such as coal, petroleum or natural gas. Those factories that use coal or petroleum to produce energy will emit lot of harmful gases such as carbon dioxide, or sulphur dioxide which can affect the environment and ecosystem. Thus, RE is suggested to use for saving our Earth.

Wind energy is one of the clean and renewable energy that can convert to electricity. However, the geometrical problem and insufficiency place for installing big wind turbine lead Malaysia less efficiently using the wind turbine system to get the electricity. Malaysia is located in lower pressure belt region which facing low wind speed problem causes investors are not interest in building wind turbine at here. (Belhamadia, 2014) The cost of installing a big wind turbine is high and required professional technician and engineers to install it. Thus, mini wind turbine (MWT) for household application is proposed in this project. MWT is not only smaller in size, but also save cost as less material used and efficient to product some electricity that may help in small electric devices such as low energy garden light. Besides, it can promote the concept of green technology which is affordable and leading to an eco-friendly environment.

1.3 Objective

The objectives of this project are as follows:

1. To develop and propose a mini wind turbine design that can generate electricity for household application.
2. To conduct conceptual analysis on the structure and feasibility of mini wind turbine.

1.4 Scope of Project

The scope of this project are as follows:

1. Study the current designs of mini (small scale) wind turbine along with the market requirement.
2. Design mini size horizontal axis wind turbines using SOLIDWORK software.
3. Simulation of wind turbine component using Computational Fluid Dynamic analysis (CFD) and Finite element analysis (FEA).
4. Compare and propose the best conceptual design of mini wind turbine.

CHAPTER 2

LITERATURE REVIEW

Literature review is focused on the previous study on the mini wind turbine to obtain knowledge and information present study. In this chapter, journals and articles that related with designing mini wind turbine are reviewed. Different parameters in designing wind turbine such betz limit, tip speed ratio, power generated are discussed in it.

2.2 Brief History of Wind Turbine

Before the invention of electrical power, the wind turbine actually is modified from windmill. Windmill is a mechanical system device that convert kinetic energy from wind to mechanical kinematic energy with rotational motion. There are a lot of discussion or argument for the true inventor of windmill, but the most ancient manuscript that related with the windmill was Heron of Alexandria as one in his Pneumatica idea of 2000 years ago. According to the description in Pneumatica as " the construction of an organ which when the wind blows the sound of a flute shall be proceed." After that, Woodcroft [1851] and Schmidt [1899] used their creativity and imagination based on the description of Horn to draw the system which shown in Figure 2.1(a) and 2.1(b). (David A, Spera,2009)

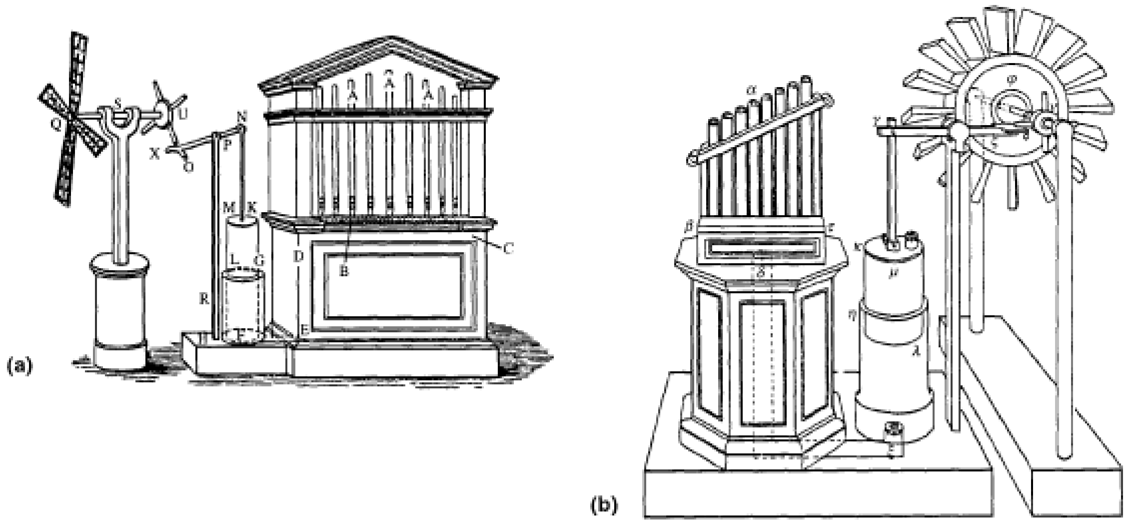

Figure 2.1 : The concept of windmill-like device that described by Heron the Alexandria in his Pneumatica (a) The horizontal like windmill drive disk and raise pinton in an air pump (b) The vertical like windmill rotor. (Spera,D, 2009)

There are different types of windmill existed in the whole world. The first recorded windmill was found in Sistan, an Eastern part of Persia on the tenth century. This is documented by trusted writer with supported ancient drawings that correspond to the remaining of old mills and to modern use. The recorded windmill was like vertical axis type which put the millstone below the rotor and grind reeds.

The first horizontal axis windmill existed in Europe during the Middle Ages. (Spera, D,2009) Then, the German crusaders bring their windmill's making skill to Syria around 1190 according to the reports. (Monthorst, 2002) This skill immigration lead the windmill technologies are spreading to the world.

After few years of evolutions, the wind turbines with generator were invented. At the 19^{th} century, the DC electrical energy is just beginning to use, thus only direct current available. The inventor and builder, Charles F. Brush built a windmill with 12 kW of DC power for charging storage batteries in year 1888.(Spera, D,2009) This invention lead the initial step in developing the wind turbine with installation of electrical generator. After this, different size and kind of wind turbines been developed and modified until becoming those modern type of wind turbine that using now in this 21th century.

2.3 Wind Turbine

2.3.1 Types of Wind Turbine

Wind turbines come in different designs with varying output and efficiencies but all of them are converting kinetic energy from wind to mechanical or electrical energy. There are several types of modern wind turbines operating in this world. Basically, the wind turbines are classified as two major type which are horizontal axis wind turbine (HAWT) and vertical axis wind turbine (VAWT).

2.3.2 Horizontal Axis Wind Turbine (HAWT)

Horizontal Axis Wind Turbine (HAWT) is a turbine that the rotational axis of have to be oriented parallel to the wind to produce power. It can be single or many blades but 2 or 3 blades are common used and most efficient. The peak efficiency of HAWT with 3 blades is high which about 50% efficiency, leading it become wind turbine industry mainstream product. (Hau, 2006) The HAWT can be determined as two types which are upwind turbine and downwind turbine. The rotor of upwind turbines is in the front of the unit, with same position with the propeller driven airplane. A tail installed at the behind the WT as yaw mechanism become one of the characteristic of it. While the rotor of downwind turbine is located at the back side of turbine. The nacelle with electric generator is designed for find the wind direction, so the yaw system is neglected. The wind direction go through the upwind turbine and downwind turbine can be seen from Figure 2.2. (Power-talk.net, 2010)

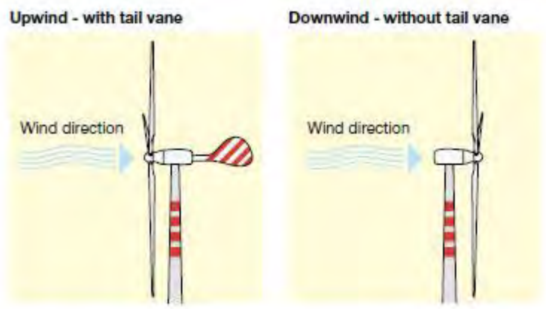

Figure 2.2: The upwind and downwind turbine with wind direction. Source: (google image)

2.3.3 Vertical Axis Wind Turbine (VAWT)

Vertical axis wind turbine (VAWT) is the turbine that the rotational axis is perpendicular to the wind direction. The generator is set up on ground become one of the advantages of it because climbing to high position is not necessary when maintaining the electric generator. It does not required yaw system. Wind speeds available are lower as its proximity to ground. (Javier Castillo, 2011) There are many kinds of VAWT such as Savonius and Darrieus or giromill. Savonius rotor is drag type VAWT while Darrieus rotor is life type VAWT. Figure 2.3 shows the different designed of modern VAWT that are being used now.

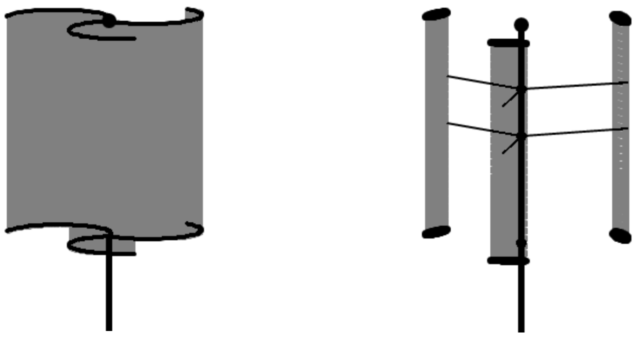

Figure 2.3: The Savonius (left) and Darrieus (right) rotor wind turbine

(google image)

2.3.4 HAWT VS VAWT

Horizontal axis wind turbine (HAWT) dominates the majorities of the wind industry. According to Hau (2006), more electricity can be generated compare with VAWT with given same amount of wind. It points into the wind direction to produce electrical power, enabling them to simplify their design and eliminate the difficulties caused by the gyroscopic on the rotor of a conventional machine when tracking the wind. The designing of removable adjust angle of attack in HAWT cause them to maximize the wind power energy generated. Besides, the cost of HAWT is cheaper in price compare to VAWT because it is higher production volume which HAWT is the major trend in market demand of whole world. Although there are many advantages, but according to research of Ozgener (2007), he proves that the HAWT is hard to start near ground area. It should have installed on high ground to operate at high efficiency. The tall tower and long blades are difficult in transportation from one place to another due to it is required specific installation procedure.

On the other hand, the vertical axis wind turbine (VAWT) have better receiving effect compare with HAWT due to the direction of inertial force and stable gravity, that according from the studies done from Tabassum and Probert (1987). Thus, the blades can receive fixed load and fatigue longevity is longer than HAWT. According to Kalantar and Mousavi (2010), the electrical components such as electric generator are installed near on ground, this make it easier path to repair or maintenance. This type of turbine does not required pointed into the wind or strong wind because it can operate under slow wind speed. But there are also have some disadvantages of VAWT. Most of the turbines are only half efficient as HAWT due to effect of dragging force. The airflow near the ground and other objects will create a turbulent flow which lead vibration of whole wind turbine.

2.3.5 Small Scale Wind Turbine

Basically, small scale wind turbines are used in housing area to generate some electricity for supplying the household application, and it is installed on the roof of building or urban area. Thus, the size of it should be small. As example, for the small size of HAWT, it can be categorized as micro (1 kW), mid-range (5 kW) and mini wind turbine (20 kW). Its swept area should not more than 200 m^2, which mean the radius of blades are not more than 8m according to the International Electro technical Commission (IEC) 61400-2. (IEC, 2006)

2.4 Lift and Drag Force

Lift and drag force are important in designing the airfoil of wind turbine. The force that exerts by the flowing fluid is called drag. Drag force actually is the combination force of pressure and wall shear forces in the flow direction. The component of pressure and wall shear forces normal to the flow that tend to move the body direction is called lift force as shown in Figure 2.4. (Cengel, 2006). The lift force is used to overcome gravity in aerodynamic, and higher lift force will lift the heavier mass.

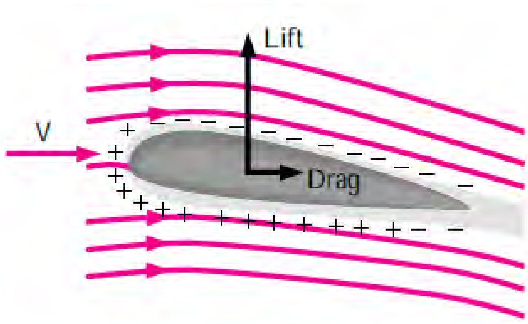

Figure 2.4: Lift and drag force (Cengel,2010)

Besides, lift and drag force coefficient are useful in determining the performance of airfoil. The equations are defined as :

Lift coefficient: $L_f = \frac{F_L}{1/2pV^2c}$ (2.1)

Drag coefficient: $L_D = \frac{F_D}{1/2pV^2c}$ (2.2)