Design And Experimental Analysis of Wind Turbine With Aeroleaf Blade

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Abstract- *This project (Design of Aeroleaf Wind Turbine) is about designing and manufacturing a Vertical Axis Wind Turbines VAWT to transfer the wind speed to a rotational motion using these turbines.These turbines will be attached to a manufactured tree that will look like a modern design, which can be installed in and around any public area such as parks, roads, public facilities, or business offices. Aeroleaf Wind Turbines are designed to produce power up to 300 watts for each turbine.*

This project presents a review on the performance of Savonius wind turbines. This type of turbine is not commonly use and its applications for obtaining useful energy from air stream is still considered as an alternative source. Low wind speed start-up, working with any wind direction, and the less noise are some advantage of VAWT- Savonius model.

This project consists of three phases; designing, fabrication, and evaluating. An actual of gained power is reported to be 31~35% relative to the theoretical gained power due to the instability and inefficient of the wind speed.

Keywords- Wind Turbines, Aeroleaf, VAWT, Savonius Model.

I. INTRODUCTION

This project is about designing and manufacturing an Aeroleaf Wind Turbine that can convert wind by using Vertical Axis Wind Turbines (VAWT) to a useful energy. The current power demanding in Saudi Arabia is very high compared to power consumption world average, as reported by Arab news; Saudis consume three times more electricity than the world average [1]. This high demanding should take the focus of attention in thinking in different sources of energy. One of the best sources of energy that can apply the concept of sustainability is renewable energy such as sun, wind, and rivers. The positive point of wind energy is that unlike solar.

Another concept of sustainability is the way that we should use in utilizing this renewable energy efficiently, and environmentally friendly. This, in turn will eliminate the environment hazard and improve Saudi Arabia communities' health and life style. Streets, public parks, schools, and public facilities are consider as main power consumers, these consumers should be vulnerable to wind from time to time. The idea of this project is to convert this wind by using Vertical Axis Wind Turbines (VAWT) to a useful energy by using it as a power source that can serve these consumers.

PROJECT OBJECTIVES

The main objective of this project is gaining power from wind. Therefore, this project is green source of energy and has no effect on the life of earth. These wind energy turbines are small and can produce up to 300 watts for each turbine. Another objective of this project is gaining and exercising some engineering concepts such as: Learn about wind energy and different ways of convert it to a useful power. Learn the different between Vertical Axis Wind Turbines (VAWT) & Horizontal Axis Wind Turbines (HAWT). Learn the impact of energy & our rules as engineering students to provide alternatives.

PROJECT SPECIFICATIONS

This project is 2.8 meter high (tree & turbine), it is expected to produce total of up to 600 watts. The material that the tree is made of is galvanized carbon steel and the turbine blades are made of aluminum alloy. The turbines can start working under low wind speed and can cut-off if the speed is too high.

PRODUCT ARCHITECTURE AND COMPONENTS

The project main components are tow turbines which include (blades, shaft bearings) for each turbine, electrical generator attached to the end of the shaft for each generator. The generators are connecting through wires to the control banal, which include (converter, controller and battery connected from and to the banal for the popups of changing from and to DC & AC). Below figure, identifying the initial functional diagram that shows the expected project outlook. And initial real photo of the project is in the below figure.

Figure: Design Model

Figure: Fabricated Model

II. LITRATURE SURVEY

There are two different styles of vertical wind turbines. One is the Savonius model, which is our project is based on, and the other type is the Darrieus model. The first model looks like a gallon drum that is been cut in half with the halves placed onto a rotating shaft. The second model is smaller and looks much like an egg beater. Most of the wind turbines being used today are the Savonius models. Renewable Energy UK website provided some information about these two model. "A Savonius is a type of vertical axis wind turbine (VAWT) generator invented in 1922 by Sigurd Johannes Savonius from Finland though similar wind turbine designs had been attempted in previous centuries.".

"A Darrieus is a type of vertical axis wind turbine (VAWT) generator. Unlike the Savonius wind turbine, the Darrieus is a lift-type VAWT. Rather than collecting the wind in cups dragging the turbine around, a Darrieus uses lift forces generated by the wind hitting aerofoils to create rotation.".
In Jun 2.15, International Research Journal of Engineering and Technology (IRJET) has published a research titled "DESIGN, ANALYSIS AND FABRICATION OF SAVONIUS VERTICAL AXIS WIND TURBINE".

This research discussion was to showcase the efficiency of Savonius model in varying wind conditions as compared to the traditional horizontal axis wind turbine. It evaluated some observation that showed that at low angles of attack the lift force also contributes to the overall torque generation. Thus, it can be concluded that the Savonius rotor is not a solely drag-driven machine but a combination of a drag-driven and lift-driven device. Therefore, it can go beyond the limit of Maximum power coefficient Cp established for the purely drag-driven machines.

Some of this researched conclusions are that The vertical axis wind turbine is a small power generating unit with the help of free source of wind energy. It is designed under consideration of household use. Generally, At least 10% power of the consumption can be fulfil by the Savonius model. The research has also resulted that this turbine is generally suitable for 8 to 10m of height above ground level. Because at ground level velocity of air is very less. And finally the alternate option for turbine blade material is reinforced glass fiber because of its more elastic nature but it is costlier than aluminum alloy.

To have the best efficiency of the power output from our turbine, the team has done some brainstorming in what are the most significant factor that affect the turbine, the blade angle was agreed to be the most significant one. By doing some researches, we fined an article that focusing in the turbine blade angle. A research article published by Advances in Mechanical Engineering (AIME) with a title of "EFFECT OF THE BLADE ARC ANGLE ON THE PERFORMANCE OF A SEVONIUS WIND TURBINE".

This article is focusing on how to improve the efficiency of the turbine by selecting the best blade angle. The effect of the blade arc angle on the performance of a typical two-bladed Savonius wind turbine is investigated with a transient computational fluid dynamics method. Simulations were based on the Reynolds Averaged Navier–Stokes equations, and the renormalization group turbulent model was utilized. The numerical method was validated with existing experimental data.

The results of this article indicate that the turbine with a blade arc angle of 160° generates the maximum power coefficient cp 0.2836, which is the highest that gain from the experiment..

III. SYSTEM DESIGN

DESIGN METHODOLOGY

The methodology applied to this project can be divided into six phases. These phases are information gathering, concept generation, model generation, model analysis and refinement, concept selection, and verification, these phases are shown in figure below.

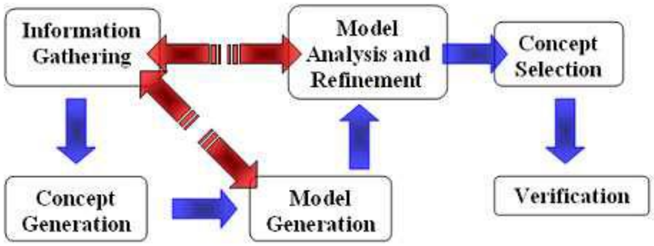

Figure: WORKING PRINCIPLE

Prior any appropriate solution can be developed, a thorough investigation has to be conducted in order to find out what solutions have already been proposed (information gathering). Once these solutions have been analyzed and the team has an understanding of why the respective solutions are not currently being implemented, a solution generation phase is taking place. Here various solutions are presented and evaluated against criteria and constraints (concept generation). Solution concepts are then modeling

The results of the models are then analyzed and the model, as well as solution parameters, may be tweaked (model analysis and refinement). Once the team has satisfactorily modeled all solution concepts of interest, the concept that performs best analytically, in addition to meeting all criteria and constraints, is selected Figure 3.2

Applied Phases of used Methodology 18 (concept selection). The analytical model may then be verified experimentally, using a small scale modeling scheme or through a full scale experimental model. The objective of this project is to design a vertical axis wind turbine (VAWT) that could generate power under relatively low wind velocities. To accomplish this goal, the objectives are to:

Analyze how different geometry of the wind turbines would affect the output power of the wind turbine. Vibrations analysis by testing how the vibrations caused from the rotations of the wind turbines affect the structural integrity of various aspects buildings structures.

Compare the operation of turbines with respect to the numbers of attached plades.

- To meet the above objectives, the tasks were to:
- Conduct background research and analysis on wind turbine technology.
- Design initially turbine blade for testing.
- Design tree to hold these turbines.
- Looking for power generator that has good efficiency with low startup speed.
- Create experimental set up.
- Manufacture parts and build model tree.
- Develop future design recommendations.

ROTOR BLADES

Savonius blades are a crucial and basic part of a wind turbine figure 3.4. They are mainly made of aluminum, fiber glass or carbon fiber. We selected the aluminum alloy as recommended in the study mentioned in chapter 2.2 because they provide batter strength to weight ratio.The design of the individual blades also affects the overall design of the rotor. Rotor blades take the energy out of the wind; they capture the wind and convert its kinetic energy into the rotation of the hub.

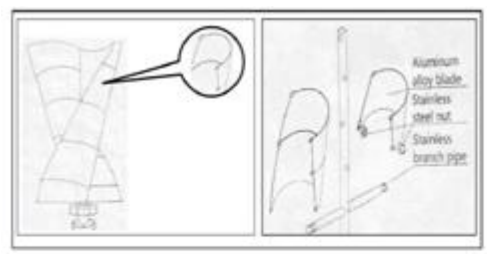

Figure ROTOR DESIGN

SHAFT

The shaft is the part that gets turned by the turbine blades. It in turn is connected to the generator within the main housing. A solidworks tools have been used in designing the blades and the shaft as shown in the below figure

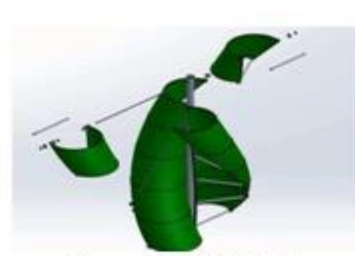

Figure: SHAFT DESIGN

TURBINE DESIGN & SKETCH

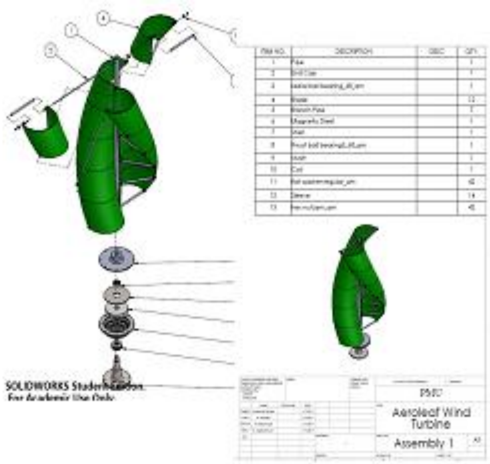

Figure: MODEL

DESIGNING TREE MODEL

At this stage, we reached to a point where we need to start planning for designing the tree. This planning starting from defining the high and width of the tree, which we agreed leader to be 2.8 meter high to achieve as much wind as possible and 2 width. A goal for defining a tree branches was to have the most popular design and material that would be able to provide realistic results. Initially, we tried to use aluminum material for the tree branches. But, this marital will not hold the turbines easily, and if it did it will not hold them

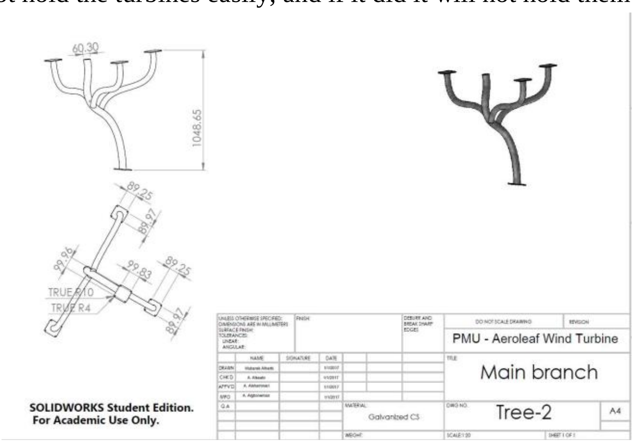

Figure: CAD MODEL

MANUFACTURING OF TURBINE BLADES AND ROD.

The vertical shaft that held the turbine was manufactured out of quarter inch stainless steel with press fits designed to attach to the generator. It also had two set screws which kept the shaft connected to both instruments as well as a set screw in the middle to lock turbine in place. The blade manufacturing was assigned to a workshop plant in Jubal using the solid work drawings and the given requirements and specifications.

The top and bottom pieces were cut out of 3/8th inch acrylic and then glued together. The metal rods used to lock the adjustable blade to the top and bottom pieces were glued together with epoxy.

Figure: MANUFACTURED MODEL

EXPRIMENTAL READINGS

After designing the components and structures desired for testing power output for win turbine designs and the structures desired to be tested, we created the experimental set-ups required to test the prototypes and structures. In order to determine the effectiveness of the products that were manufactured, we performed tests to evaluate them. The test set up was in Half Moon (open area). We also tested the power output of the turbine blades and evaluated how the vibrations from the turbine affect the stress and strain on a tree structure.

Two experiments have been conducted; the procedure of calculating the power is counting the voltage & current that feeding the battery. The power gained can be calculated using the below equation.

$$P = IV$$

Where: I is Current in Ampere, V is voltage

EXPERIMENT# 1

Experimental Readings					
Experiment# 1 Normal weather					
Time	Wind Speed m/S	Voltage (V)	Current (I)	Power (Watt)	Power (2) Trubines (Watt)
21:00	0.7	8.6	0.05	0	1
18:00	1.6	10.6	0.15	2	3
15:00	3.4	12.3	0.24	3	6
12:00	4.3	13.7	0.43	6	12
9:00	5.2	14.2	0.52	7	15

* Sorted by increasing in wind speed

Figure: TABLE 1

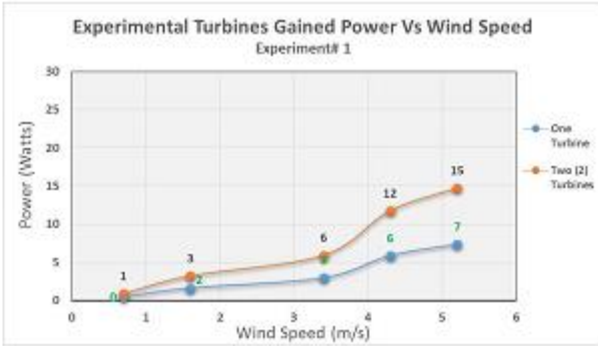

Figure: GRAPH 1

EXPERIMENT# 2

Experimental Readings					
Experiment# 2 Windy Day					
Time	Wind Speed m/S	Voltage (V)	Current (I)	Power (Watt)	Power (2) Turbines (Watt)
21:00	6.2	15.8	0.51	8	16
18:00	6.6	16.5	0.57	9	19
15:00	7.1	17.2	0.84	14	29
12:00	7.5	17.7	1.2	21	42
9:00	8.4	18.4	1.9	35	70

Figure: TABLE 2

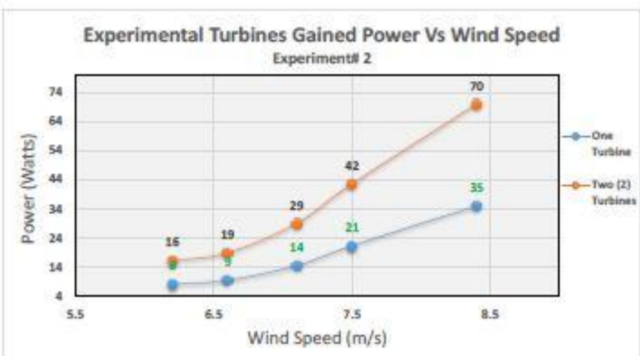

Figure: GRAPH 2

IV. DISCUSSION

As a result, This studies (experimentally and theoretically) present a review on the performance of Savonius wind turbines and show the gap between the actual and ideal output power, where a several factors have affected clearly on the actual performance, these factors are due to external factors, lack of resources, process, geometrically, or due to human error. These factor resulted in drop of 31~ 35% between the theoretical and experiment results.

When wind speed 11.6 m/s, we will reach 300 watts that our turbine can produce theoretically. Savonius rotor performance are affected by operational conditions such as Instability and insufficient of wind speed.

V. CONCLUSIONS

From our research we were able to come up with many important conclusions and suggestions which will profit the future advancement of individual vertical pivot wind turbines. We could outline a VAWT framework that enhanced power yield when contrasted with the past projects.

From our results we were able to recommend new design aspects to improve the system and efficiency. Inefficient wind speed was the huge impact getting the required power output, minimum speed of 12 m/s is required to have acceptable output power taking in consideration 31~35% of efficiency between theoretical and experimental results.

Even though we were able to make this design of Vertical Axis Wind Turbine but there is a never ending process to always improve upon inventions and new designs. Wind turbines are a start for society to lessen the damage done to the earth by not using energy sources that produces pollution. Hopefully the project could propel research and testing on VAWT frameworks and give knowledge for different gatherings to finish additionally testing and enhance productivity and execution of vertical pivot wind turbines.

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