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Design and Analysis of Vertical Axis Savonius Wind Turbine

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Abstract— In order to produce electrical energy from wind energy, the vertical axis Savonius wind turbine's design and analysis are presented in this work. Due to the global energy crisis and increasing global emissions, research and development efforts in the field of renewable energy, particularly wind and solar, have significantly grown in recent years. It is not possible to operate a horizontal axis wind turbine for domestic use. Because it can function in low wind conditions as well, the Savonius vertical axis wind turbine may be a preferable option. This type was chosen to demonstrate its effectiveness in a variety of wind conditions in comparison to the conventional horizontal axis wind turbine and to support its gradual growth in popularity for the objective of widespread adoption as a dependable source of power generation in the near future.

Keywords-Vertical axis wind turbine, Savonius, Rotor blade, Rated wind speed, Aspect ratio, Solidity

I.INTRODUCTION

Due to the problems with the 1973 oil crisis, developments in renewable energy, notably wind energy, became widespread. Almost 90% of the energy used in the world today comes from burning fossil fuels, such as coal, regular gas, petroleum oils, etc. Most people utilise fossil fuels to fulfil all of their energy needs, including driving their cars, lighting their homes, and operating their businesses. The growth of the population will increase both the demand for energy sources and the price of fossil fuels. The global environmental change brought on by carbon dioxide and sulphur dioxide emissions from the use of fossil fuels is also a problem. by utilising renewable energy to cut back on the carbon emissions produced by transportation and industry. Additionally, it is economical. Due to the lack of carbon emissions, renewable energy is an environmentally favourable energy source. According to the international energy agency, just a small portion of the world's energy comes from hydropower and nuclear power, and a much smaller portion comes from renewable energy sources like wind, solar, biomass, geothermal energy, and tidal waves. Wind energy is an environmentally benign energy source that also helps to mitigate the effects of greenhouse gas emissions from the combustion of fossil fuels on the environment. The estimated amount of energy produced by wind in the world is 10 million MW.

Wind energy is captured by a wind turbine that is mounted on top of a tower and transformed into power that is compatible with a home's electrical system. Our electricity cost is generally reduced by 50% to 90% thanks to the wind turbine. Approximately 9,400 kilowatt hours are used by homes. annually in (kWh) of electricity (about 780 kWh per month). A wind turbine with a rating between 50 watts and 15 kilowatts would be needed to significantly contribute to meeting this demand, depending on the typical wind speed in the area. Depending on size, purpose, and servicing, a tiny turbine may cost up to Rs 20,000. They are totally autonomous and have a lengthy lifespan (up to 20 years).

II.LITERATURE SURVEY

Relating to the current stated work a literature survey was carried out. The summary of the reviewed papers is given below.

A research paper entitled "Experimental Study for Savonius Wind Turbine with Two and Three Blades at Low Wind Speed" was delivered by Mohammed Hadi

Ali, a lecturer at the University of Mustansiriya. In order to analyse the performance of the two-bladed and three-bladed Savonius wind turbines and compare them to determine which one performs better than the other, the experiment's methodology was carried out and tested in the wind tunnel. The performance of the dimensionless parameters torque coefficient ($C\tau$) and power coefficient (Cp) was assessed at low wind speeds in terms of starting acceleration and maximum no-load speed as a function of the dimensionless parameter tip speed ratio ((λ). [1]

[2] A research paper on the "Design, Analysis, and Fabrication of Savonius Vertical Axis Wind Turbine" was delivered by Prof. Vaibhav Bankar and Ashwin Dhote. The same conclusions from this research are as follows: [2]

[1] At least 10% power of the consumption can be fulfilling by this set up.

[2] Multi stage generator is the double generation concept with the same size rotor.

[3] Gear arrangement can increase the number of rpm in case of low wind speed.

[4] This turbine is generally suitable for 8 to 10m of height above ground level. Because at ground level velocity of air is very less.

[5] Combination of alternator with gear arrangement can be used to increase output but unnecessarily it will increase the cost of machine.

[6] Considering the all-weather point of view the material use should be non-corrosive.

A research paper titled "Comparison of Horizontal Axis Wind Turbines versus Vertical Axis Wind Turbine" was presented by Magedi Moh. M. Saad and Norzelawati Asmuin. In this essay, the horizontal axis wind turbines (HAWTS) and vertical axis wind turbines (VAWTS) are contrasted. The two different types of wind turbines are employed for various tasks. Both VAWTs and HAWTs are used to harness the wind's energy in order to produce electricity. Both forms have been compared in this paper, along with their benefits and drawbacks. Every kind has a specific use. The location to be fixated on and the wind speed will determine this. Anyhow, due to its efficiency of roughly 60%, the horizontal axis with propeller blades is the most popular. [3]

III.WORKING OF SAVONIUS WIND TURBINE

The Savonius or so-called "S" rotor's operating principle is quite straightforward and is very similar to the one seen on basic cup anemometers. The torque on the main holding shaft is produced by the drag force produced by cup- or semi-cylinder-like surfaces (scoop), producing power that can be used for a variety of tasks. It is demonstrated that, in the case of a Savonius rotor, geometrical features such the separation distance between scoops, overlap ratio, and aspect ratio are crucial for the rotor's optimum performance.

We therefore define those parameters through the following relations:

Aspect ratio: AR = Hs / Ds

Overlap ratio: OL = a / Dc

Separation gap: GP = - b / Dc

Where, Hs = Height of savonius rotor.

Ds = Diameter of savonius rotor.

a = Savonius rotor overlap.

Dc = Diameter of savonius rotor semi cylinder.

B = Savonius rotor separation gap.

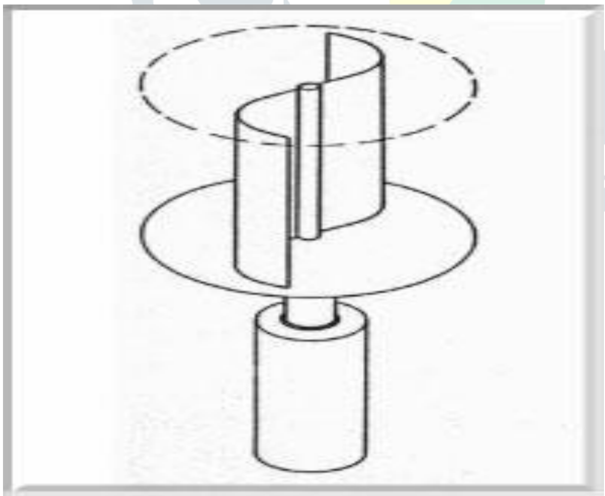

FIG 1: Savonius Rotor

A Savonius wind turbine is made up of two, three, or six half cylinders facing in opposite directions so as to form a cross section that is practically S-shaped. These two semi-circular drums are separated by a gap at the axis and are mounted on a vertical axis that is parallel to the direction of the wind. No matter which way the wind is blowing, the rotor turns so that the convex side of the buckets faces the wind. Each of these inner edges should be close to the centre axis of the opposing cylinder, rather than having each pair of edges overlap to form an S-shaped shape. The wind's primary effect is pretty straightforward: the cupped face receives more wind force than the rounded face. As with the airflow over the top of an air foil, the wind that curves around the back side of a cupped face produces a lower pressure, which aids in rotation. The air can whirl around inside the forward-moving cupped face thanks to the large gap between the two inner edges of the half cylinders, pushing both in the rotational direction.

IV.SAVONIUS WIND TURBINE ADVANTAGES

[1]Savonius wind turbines may run in any wind direction because: Unlike other wind conversion technologies, Savonius wind turbines do not need to be installed with the rotors facing a flowing wind current. Any direction can be used by the rotors to capture wind energy for use as mechanical energy. This is possible because Savonius wind turbines are able to recognise and capture the wind from any direction.

[2]Savonius wind turbines have an increased airfoil pitch angle, resulting in enhanced aerodynamics and reduced drag at low and high pressures.

[3] Low height is advantageous in situations where building height restrictions apply. is significantly less expensive and more powerful in strong winds that are near to the ground because it does not require a free-standing tower.

[4] If the moving components are close to the ground, maintenance may be simpler. Because the wind is propelled up a slope or channelled into a pass and into the path of VAWTs located close to the ground, mesas, hilltops, ridgelines, and passes can have quicker winds close to the ground.

V.IMPORTANT CHARACTERISTICS OF DRAG FORCES

1) Drag Force increases with the Area Facing the Wind: - Drag force increases in proportion to the swept area of an object facing the wind. In savonius maximum drag force is required to incident on cupped face than on the round face.

2) Drag Increases with the Square of the Wind Speed: Both lift and drag increase with the square of the wind speed.

3) Drag Increases with the density of air: - Both lift and drag increase in proportion to with the density of air. Cold air will thus give more drag than hot air. We can find the density of air at different temperatures in the Reference manual.

4) Drag Force Formula: - The drag force for a given object can be found using the formula below:

$Fd = x\ 0.5\ x\ A\ x\ V^2$

Where,

Fd = The drag force measured in N (Newton)

Cp= The drag coefficient, measured in N/ m^2, i.e., the drag force per square meter swept area of the object shape.

This value is usually found through (very expensive) wind tunnel measurements.

A = Swept area of the object in m^2,

VI.CALCULATION OF WIND POWER

1) The power output of a wind generator is proportional to the area swept by the rotor - i.e., double the swept area and the power output will also double.

2) The power output of a wind generator is proportional to the cube of the wind speed - i.e., double the wind speed and the power output will increase by a factor of eight (2 x 2 x 2)!

Power available in wind

Following values have been considered for designing Savonius wind turbine is shown below

- Diameter =20cm
- Area = 0.5 meter
- Cp = 0.3
- $\lambda = 1$
- $\rho = 1.22$
- V = 9m/s

TURBINE CALCULATIONS

- Calculation for development of a design model for mentioned application:
- 1.Wind power = ½ ρ A V^3 =½ *1.22*0.5*9^3

  Pw= **222.345W**
- 2. Rotor power = ½ ρ A V^3 Cp = ½ *1.22*0.5*9^3*0.3 Pr=**66.7035W**
- 3. Efficiency= Pr/Pw = (2223.45/667.035) *100

  η =**33%**
- 4. Angular speed ω= λ* V/R =1* 9/0.1

  ω=**90**

Where, P = power in watts (746 watts = 1 hp) (1,000 watts = 1 kilowatt)

ρ = air density (about 1.225 kg/m3 at sea level, less high up)

A = rotor swept area, exposed to the wind

Cp= Coefficient of performance (.59 {Betz limit} is the maximum theoretically possible, 0.45 for a good design)

V = wind speed in meters/sec (20 mph = 9 m/s)

SIMULATION MODEL

- After getting the circuit next procedure is modeling and simulation. At the beginning the software's tried to simulate the circuit are P-spice and MATLAB Simulink. P-spice is not suitable to model the wind turbine because they don’t have some of the main components. So, the good decision is by using MATLAB Simulink since it has all the components, user friendly and easy to get the data by using some specific toolbox.
- After understanding some of the examples given, and then tried to develop our own model of wind energy system.

SIMULATION CIRCUIT

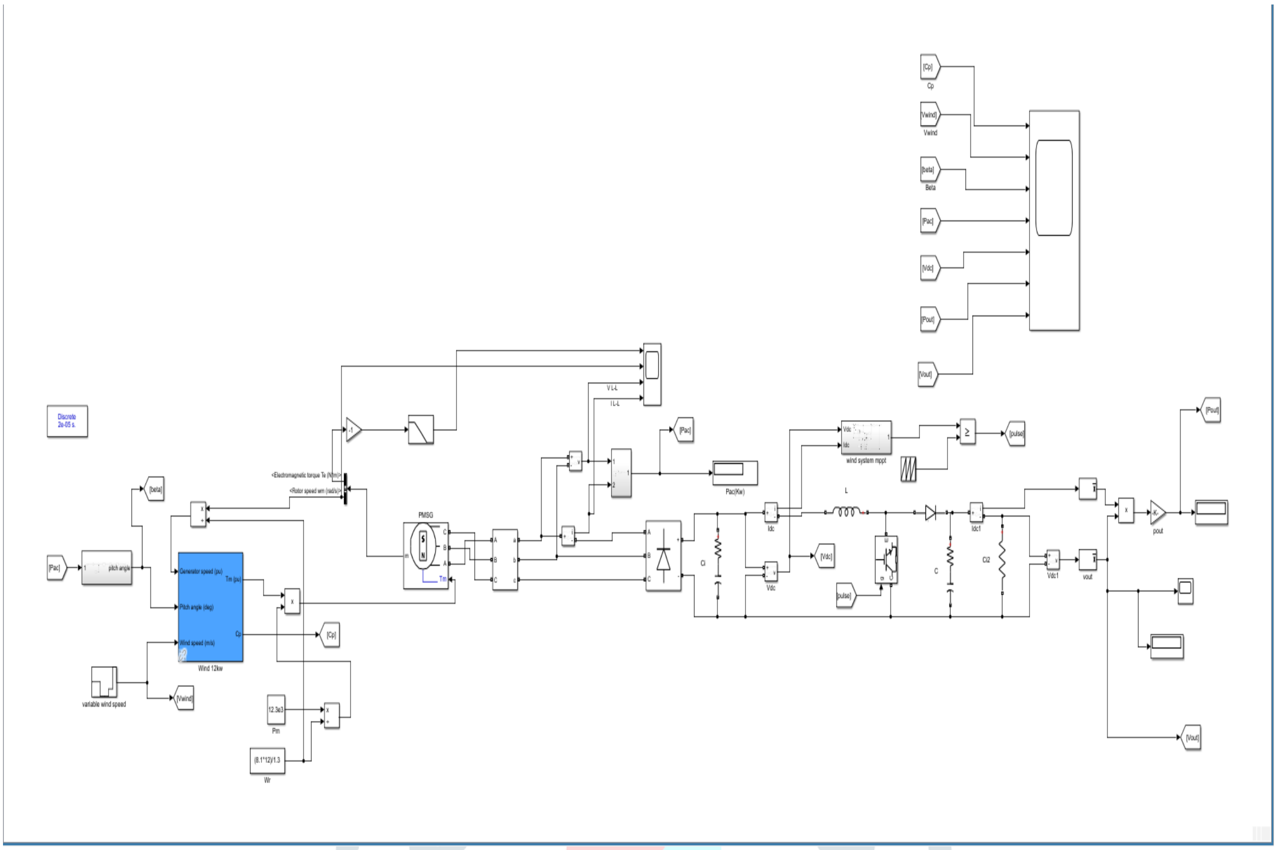

Fig 2, Simulation circuit

SCOPE GRAPHS

- The above graphs provide the waveforms for wind speed, power, torque, voltage, power, coefficients of power drag and lift is provided in fig below.

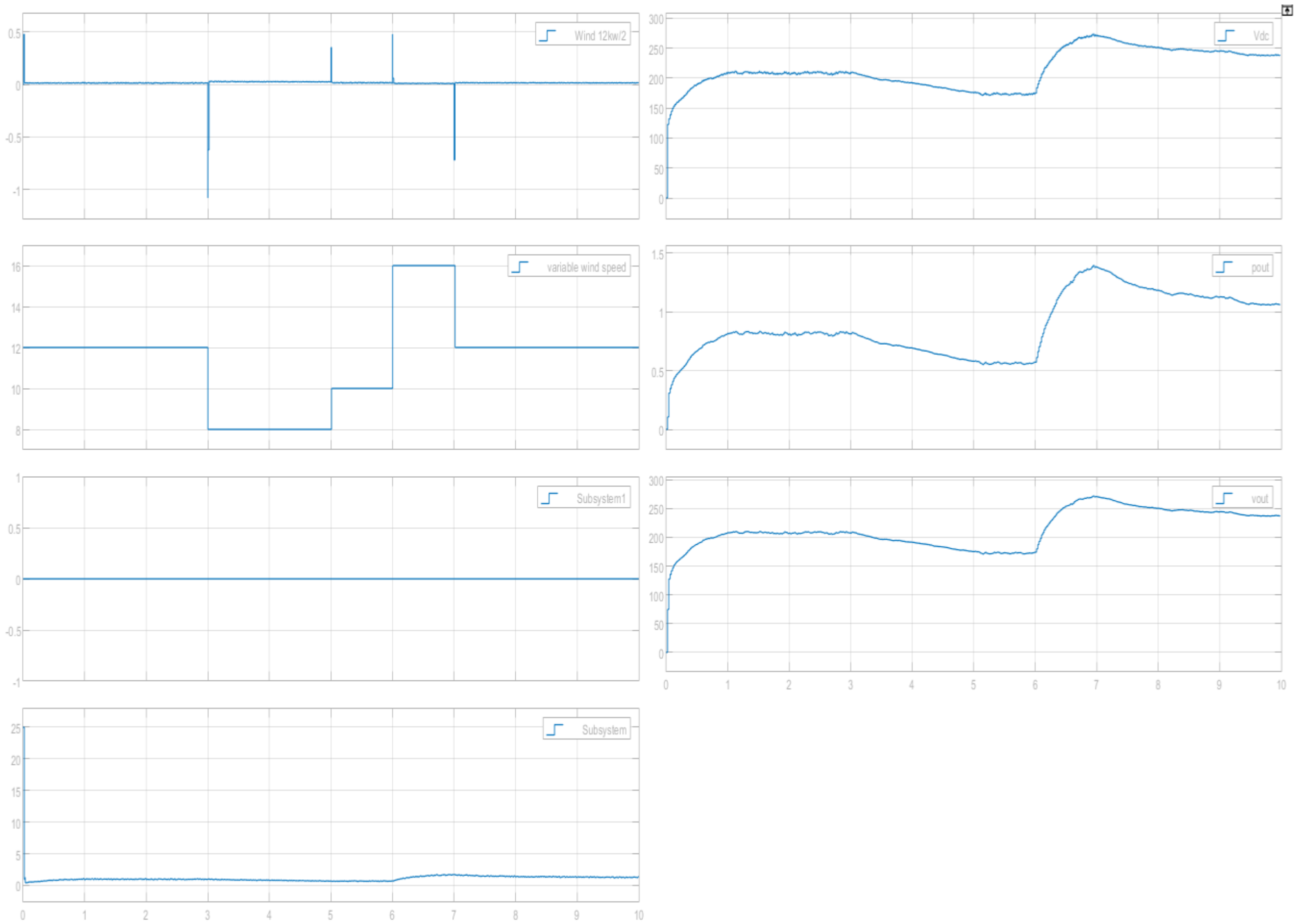

Fig 3. graph of power v/s torque, lift v/s torque, drag v/s torque

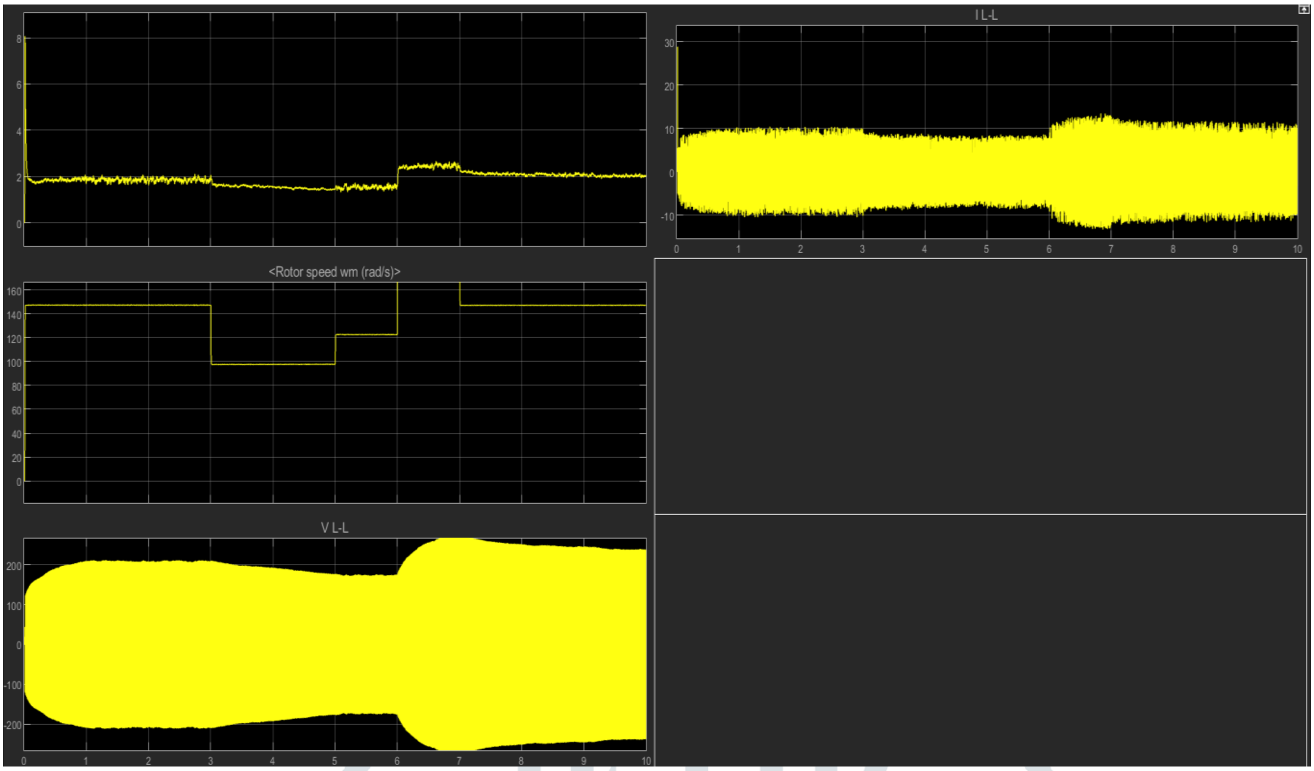

Fig 4, graph of voltage v/s load, current v/s load, rotor speed v/s load

The following graph provides the waveforms for wind speed, rotor speed, voltage vs load, voltage vs current provided in fig below.

FUTURE SCOPE

- This project aims in future for huge possibilities to invent vehicles runs on electricity because of rapidly decreasing the storage of fuel, and people use this to charge their vehicles to reach their destiny.
- The efficiency is increased by precise fabrication of prototype, by designing the blades of the turbine more aerodynamically and use simulation software like CFD.

CONCLUSION

A vertical axis wind turbine, especially Savonius turbine has the eligibility to work at low wind speed so in this project it is modelled for its optimum operation for low wind speed conditions of 4 to 6 m/s and generator speed of 155 rad/sec to produce mechanical power output.

The project also gives the variation of power, torque, angle of attack, lift coefficient, drag coefficient, lift force and drag force V/s Azimuth angle from 0 to 360 degrees.

The performance of wind turbine is observed by varying wind speeds and corresponding output is noted. It is observed that the proposed project gives the mechanical power output of 120W, 280W, and 520W for the wins speed of 4m/s, 5m/s and 6m/s respectively.

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[2] Frederikus Wenehenubun, Andy Saputra, Hadi Sutanto. An experimental study on the performance of Savonius wind turbines related with the number of blades. Energy procedia 68 (2015) 297-304

[3] Mohammed Hadi Ali Lecturer University of Mustansiriya presented research paper on “Experimental Study for savonius Wind Turbine of Two and Three Blades at Low Wind Speed”.

[4] Prof. Vaibhav Bankar and Ashwin Dhote presented research paper on “Design, Analysis and Fabrication of Savonius Vertical Axis Wind Turbine”.

[5] Magedi Moh. M. Saad, a, Norzelawati Asmuin presented research paper on “Comparison of horizontal axis wind turbines and vertical axis wind turbine”.