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Recent Advancement in Savonius Wind Turbine- A Review

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***Abstract:** In the steps to save our earth from global warming every nation focused on their own way to promote green energy among which the Savonius vertical axis wind turbine is one of the excellent viable solutions for scavenging wind energy in a downtown background, due to distinctive characteristics such as compactness, self-starting ability at light wind, minimum noise level, with relatively reasonable price and simple assembly. However, the traditional Savonius Wind Turbines with semicircular blades has a proportionately low power coefficient together with a high negative torque produced by the returning blade is a crucial disadvantage of this rotor. This work focuses on reviewing and giving an overview on the form of the wings of Savonius Vertical Axis Wind Turbine. This paper also aims to give a run through of the several augmentation approaches used in Savonius rotor over the last four decades. In this paper, a brief on all possible segments and parts of the machine is given after a brief analysis and research on each topic.*

***Keywords:** Green Energy, Savonius VAWT, Geometric Parameters, Performance Improvement.*

1. INTRODUCTION

The increase in the use of non-renewable energy has increased global warming which causes a lot of disturbances in the stability of our planet earth. To make it a safe place to live in, we have to reduce all possible ways in which it causes imbalance, like reducing the use of non-renewable sources to generate energy and reduce pollution which will certainly reduce the level of global emissions which will save it a lot. In this situation, renewable sources like wind, hydel, and solar are the best option on which we must shift our dependency [1]. Among all of the other renewable sources, the wind is an efficient option to choose. There is a certain reason to choose wind because it is far cheaper than any other renewable resource.

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There are mainly two varieties of turbine namely- vertical axis wind turbines and horizontal axis wind turbine. Between these varieties, both have both pros and cons among themselves. The Horizontal Axis Wind Turbines are in major use in commercialized generation of electricity as it has greater efficient design to extract more energy by full blade rotation and many more. But it has a lot of disadvantages like difficult maintenance, one sided rotation and causes lot of hazards. A close look into the concepts will lead researchers to the point that for generating electricity in many conditions like turbulent wind flows and high wind velocitiesVAWT are the appropriate choice where HAWTs have failed to give efficient generation of electricity. Another crucial point in VAWTs is that they are bi-directional which can accept winds from any direction without any extra mechanism.

Fig. 1: Horizontal Axis Wind Turbine
(Source: Dennis Schroeder | NREL 25897)

Fig. 2: Vertical Axis Wind Turbine
(Source: Mike van Bavel | 42795)

Theoritical Background

The principle behind wind turbines is that the dynamo or generator generates electricity through the mechanical energy of flow of the air mass, which comes from the wind's kinetic energy. It is then used as many households' application as electricity [2-4].

A. Betz's Law

It states the maximum efficiency thatwind turbines can be produce theoretically. As stated by Benz's law,16/27 (59.3%) is the maximum amount of extractable kinetic energy of the wind [5].

B. Tip Speed Ratio

Denoted by Lambda (λ), it symbolises the ratio of the tip speed of the blade to the wind speed.

$$\lambda=\frac{v_{tip}}{v_{wind}}$$

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C. Power Curve

It is a graph that defines net production of turbines at different wind speeds. The typical power graph or curve has been plotted in Aymane et al.[7].

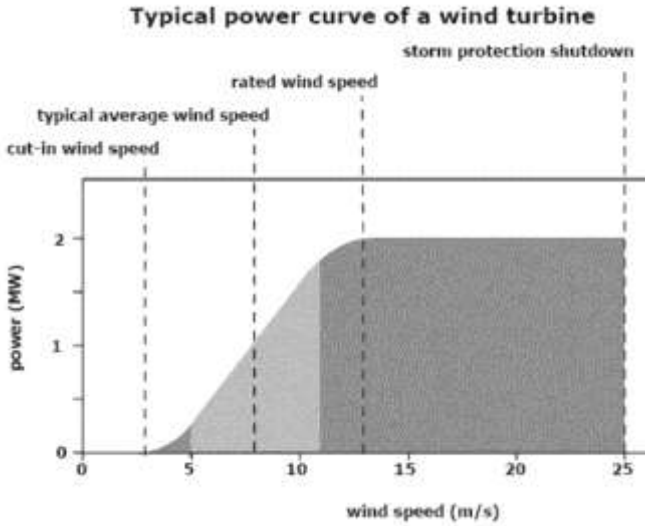
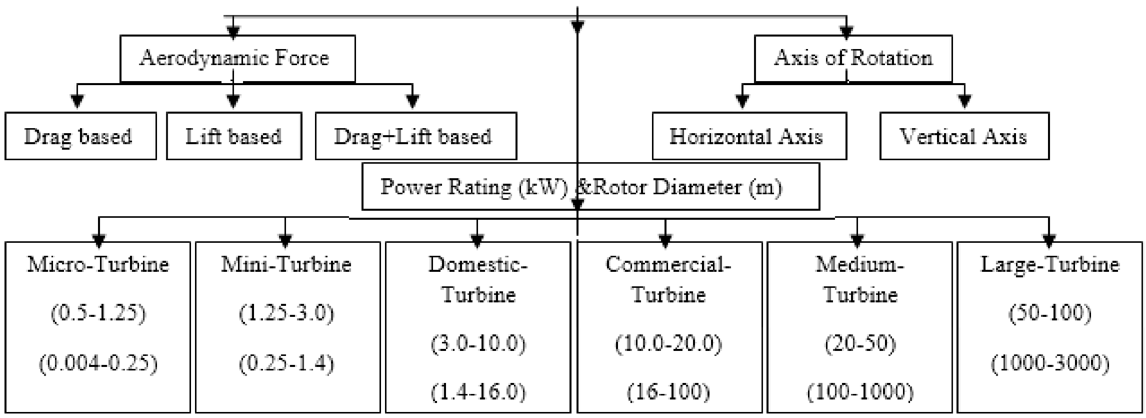


Fig. 3: Typical Power Curve of a Wind Turbine [7]

Types of Wind Turbine

Classification of Wind Turbines can be done upon rotation's orientation axis, the power capacity of turbines, and the drag or/and lift forces experienced by the blades, and. Mainly there are three types of classification- base on axis of rotation, based on rotor diameter and power rating and based on aerodynamic force.

Table1: Wind Turbines Classification
Classification of Wind Turbines



A. Types of Wind Turbine Based on Axis of Rotation

Based on the centre line of rotation there are few varieties of Wind Turbines namely-Horizontal Axis Wind Turbines and Vertical Axis Wind Turbines. The HAWTs are turbines

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whose centre line of rotation points horizontal on the ground and blades are unidirectional [9-10]. They have self-started system by yawing mechanism. The turbines in which the axis of rotation has a vertical direction and it generates energy from omni-directional winds with minimal speed are called Vertical Axis Wind Turbines. They are discussed with more detail below. [11-12].

B. Types of Wind Turbine Based on Aerodynamic Force

The other types of turbines based on aerodynamic force of the wind on the turbine – drag based turbine, lift based turbine and drag and lift both at the same time [13]. The differentiating factor between drag based and lift based turbines is the direction of the aerodynamics force in relation to the flow of air, parallel in case of drag based, and perpendicular in the case of lift based turbines. Examples of purely lift based turbines are HAWTs and Darrieus turbines, while examples of drag based design include some new designs of VAWTs including Savonius [14]. Lift based turbines have the advantage of generating more energy per wind swept area, while being more complex than drag based designs.

C. Types of Wind Turbine Based on Rotor Diameter and Power Rating

Based on the power rating and rotor diameter it may also be classified into six types namely Micro Turbines, Mini Turbines, Domestic Turbines, Commercial Turbines, Medium Turbines and Large Turbines. Micro Turbines are those whose Rotor Diameter is about 0.5- 1.25 m and power rating of 0.004-0.25 Kw. Mini Turbines are those whose Rotor Diameter is about 1.25- 3.0 m and power rating of 0.25-1.4 Kw. Domestic Turbines are those whose Rotor Diameter is about 3-10.0m and power rating of 1.4-16.0 Kw. Commercial Turbines are those whose Rotor Diameter is about 10.0-20.0 m and power rating of 16-100 Kw. Medium Turbines are those whose Rotor Diameter is about 20-50 m and power rating of 100-1000 Kw. Large Turbines are those whose Rotor Diameter is about 50-100 m and power rating of 1000-3000 Kw. As an alternative of HAWTs, VAWTs or Vertical Axis Wind Turbine has its axis of rotation perpendicular to the wind directions and ground. They are generally simple. VAWTs are slow and silent, therefore can be installed among an urban environment. A peak area of interest about VAWTs is making them more efficient in slow winds. [15].

VAWTs

The turbines in which the axis of rotation has a vertical direction and it generates energy from omni-directional winds with minimal speed are called Vertical Axis Wind Turbines or VAWTs. These turbines in general produce less noise than HAWTs and also weigh lesser than them hence can be easily integrated into any high apartments.The VAWTs work on the principles of aerodynamic drag forces. Researchers have focused in reducing the drag effects and increase the lift forces, in order to increase the aerodynamic efficiency. The VAWTs can be further categorized into two groups namely Savonius and Darrieus. This paper is a review of the Vertical Axis Wind Turbine and more specifically on Savonius wind turbine [16-17].

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Fig. 4: Savonius Wind Turbine
(Source: Toshihiro Oimatsu)

Fig. 5: Darrieus Wind Turbine
(Source: Wikimedia Commons)

Savonius Wind Turbine

Savonius Wind Turbine had invented by Finnish engineerSigurdSavonius in 1922 which is based on drag forces. It is efficient and simplest Wind Turbine with lowest cut in speed of wind. Its design consists is such that a near perfect 'S' shape is formed by two half cylinders. It's USP is that unlike many any other lift-based turbines, the Savonius turbine can start itself. The drag force by the wind acting on the half cylinders generates the torque. The maximum value of power co-efficient for this turbine is observed to '0.3'. The difference of the force that the incoming air produces on the convex and concave parts of the blades causes the turbine to rotate.The production of torque takes place by the rotation of the blades caused due to mechanical force of air trapped inside the concave part of the blades pushing against them. More than two blades can be added to because it spin more to produce more drag [18-27].

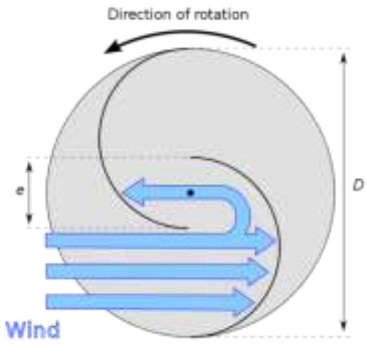

Fig. 6: Working of a Savonius turbine
(Source: By Ugo14 - Own work, CC BY-SA 3.0)

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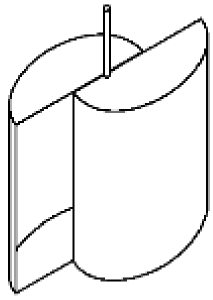

Fig. 7: Schematic drawing of a basic Savonius turbine
(Source: By Original: Rottweiler Vector: Cmglee**)**

Characteristics of Savonius Wind Turbine

Swept area of Savonius Wind Turbine is characterized by $\boldsymbol{A_S}$ which influences the produced energy output of the turbine. More A_S means more energy output.

$\boldsymbol{A_s = H*D}$ where D is its diameter and H is the height of the turbine[28].

The equation which defines the tip speed ratio of the rotor:

$$\boldsymbol{\lambda} = \frac{V_{rotor}}{V} = \frac{\omega * d}{V}$$

where V= speed of wind,
ω= angular velocity of the turbine,
And d = diameter of the semi-cylindrical blade[28].

The rotor's torque vs. the theoreticaltorque that the wind can cause is the ratio of **torque coefficient C_{ts}.**

$$C_{ts} = \frac{T}{T_W} = \frac{T}{\frac{1}{4}\rho * d * A_s * V^2}$$

where T = torque in the rotor and ρ= air density.

The ability of the turbine to self-start is denoted by the static torque coefficient C. It is the ratio of the maximum static torque in the turbine vs. the theoretical wind torque:

$$C = \frac{T}{T_W} = \frac{T}{\frac{1}{4}\rho * d * A_s * V^2}$$

Where, T_s= maximum static torque.

The following equation is for the rotor's torque calculation:

$$\boldsymbol{T = I * \alpha},$$

whereI= rotor's moment of inertia
and α= rotor's angular acceleration[28].

The ratio of the extracted power from the wind to theavailable power in the wind is the power coefficient Cp:

$$C_p = \frac{P_\omega}{P_a} = \frac{T * \omega}{\frac{1}{4}\rho * D * H * V^3}$$

Using these characteristics, we can find and analyse the performance of the Savonius Wind Turbine. Experiments proven that Savonius wind turbine can generate well in low wind speed of around 2.5 m/s^2. Research suggests that the performance of two blades is better than their three blades' counterparts because of the wastage of drag in three blade systems. But four blade systems can perform better than two blade system at low tip speed ratio [29-30]

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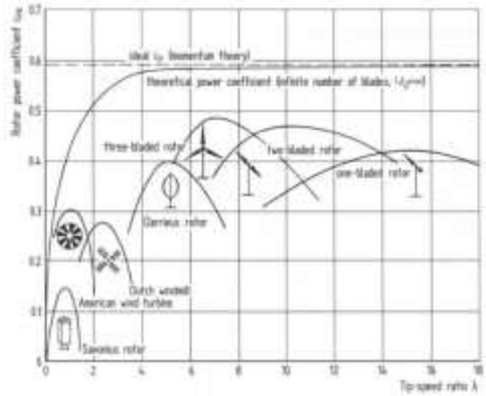

Fig. 6: Graphical dependency CP = f (λ) for different types wind turbines as seen in Ahmed Ahmedov [31]

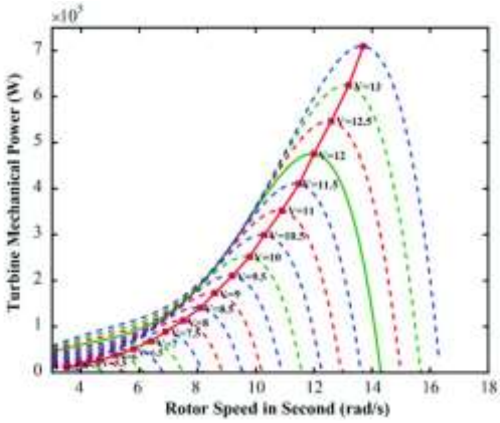

Fig. 7: Turbine mechanical power curve vs. rotor speed under variable wind speeds as seen in Sarkar et al. [32]

2. CONCLUSIONS

As conclusion, we may consider the following points for recommending Savonius wind turbines.

- They are independent on any direction of the wind with no additional mechanisms.
- It has the ability to function in any wind conditions for example in Turbulent or low wind speed.
- Low sound level.
- High torque during start.
- Small and Compact in Size. Simple and cheap in construction.
- All the above features make Savonius Wind Turbine a good choice for use in residential areas like high apartment or make it suitable for use beside high-speed railway tracks or roads where there is more or less greater wind blasts to make it rotate and generate electricity.

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