Review Paper on Vertical Axis Wind Turbine

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***Abstract*- This paper presents the literature review of vertical axis wind turbine. The vertical axis wind turbine based on the Savonius-rotor type. This system can generate electricity using the wind energy. In a current scenario usage of fossil fuel causing pollution and liberation of greenhouse gases in environment which is very dangerous for humans as well as to the earth. But without electricity, electric appliances cannot work. This system uses energy which is freely available everywhere to generate electricity. This system can be constructed in remote and urban area. This system can be used for highway lightning and on the petrol pumps to run the electrical equipments on petrol pumps. The major advantage of vertical axis wind turbine is it uses green energy, low speed start up, silent in operation.**

I.INTRODUCTION

The simultaneous increase of population and energy demand, turn on natural resources capacity in a real strained situation, and in other hand, utilization of fossil fuel resources of energy is becoming more restricted mainly because of declining in fossil fuel reservoirs, threatening global warming, and the increase of oil prices. Therefore harnessing clean and renewable sources of energy is becoming the main worldwide topic for many researchers [1]. Wind energy has long been recognized as a potential source and a significant part of the electricity generation of renewable energy. The importance of wind energy resource is being realized all over the world and has been taken as one of the most attractive renewable energy options in terms of cost effectiveness and environmental impacts. Vertical Axis wind turbines are capable to extract wind energy in all directions due to their Omni-directional nature. This is major advantage of vertical axis wind turbine over horizontal axis wind turbine [2].

II. LITERATURE REVIEW AND METHODOLOGY

A. VERTICAL AXIS WIND TURBINES (VAWT)

VAWT is a turbine whose axis of rotation is pointed in vertical direction. VAWTs can produce electricity from wind of any direction with low cut-in wind speed. These turbines are significantly quieter than the traditional HAWTs, lightweight, and can be easily integrated into buildings. These turbines are based on the aerodynamic drag forces, except Darrieus types. The research efforts on these turbines are focused on increasing the aerodynamic efficiency by reducing the drag effect and increasing the lift forces. It was predicted that they could be an efficient solution for the built-up areas where the wind is unstable. The designs of VAWT can be categorized into two groups, viz. Savonius and Darrieus [3].

B. SAVONIUS TYPES VAWTS

Finnish engineer Savonius had invented this type turbine in 1920, principally based on drag force. This is the simplest WT with low cut-in wind speed, it usually consists of two half cylinders facing opposite directions in such a way that they have formed almost an S-shape (Fig.1). The main drawback of this design is poor aerodynamic performance in comparison to other turbines. Savonius might be a preferred choice if power reliability is more important than turbine efficiency or COE. Concentrated efforts have been made on making Savonius as an efficient design of WTs for urban areas, which include modifications in the rotor design, blade shape, blade overlap, and the number of blades. These turbines exhibit uniqueness in terms of rotor design and torque production. The power coefficient varies with the configurations of the rotor design.

Roy and Saha conducted several wind tunnel experiments with a two-bladed Savonius turbine, mainly planned for small-scale power applications. Simultaneous tests were also performed with other blade configurations to make a comparison of performances. A notable gain of 34.8% was recorded for two-bladed Savonius rotor. In a subsequent study, Roy and Saha applied computational methods to study the operating parameters of Savonius. It was noted that the differential drag force spins the turbine, but also primary reason for poor aerodynamic effect. Efforts have also been made to minimize the drag effect by varying the blade numbers, orientation, and blades overlapping. The variation in the blade numbers influence the power coefficient and the best performance was seen with three blades [3].

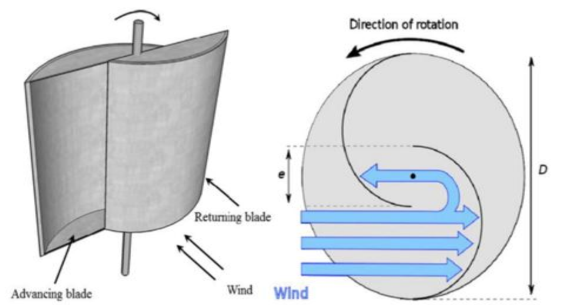

Fig.1. A sectional view of Savonius turbine and operational mechanism [3]

C. PERFORMANCE OF SAVONIUS TURBINES

The other traditional design of VAWTs is the Savonius. As mentioned, the Savonius rotor is a drag-type machine, consisting of two or more blades (Fig.1). These turbines have achieved some level of acceptance due to their low cut-in wind speed sand self-starting capability but suffer from a low rotational performance and overall efficiency. Akwa et al. performed a detailed study on Savonius turbines and concluded that a diversity of rotor configurations is a useful characteristic of this type machine. The aerodynamic performance is affected by the geometry of the rotor, air flow characteristics, and operational conditions. The power coefficient of different designs of Savonius varied and evaluated in the range of 0.05–0.30. Roy and Saha reviewed the performance evaluation methods of these turbines. They concluded that the computational methods can be an effective strategy for the advancement of Savonius design with minimum expense. Efforts have also been made to increase the aerodynamic efficiency. The modifications in the blade shape, size, and orientation was also analyzed [87–90]. It was recommended that the design, aerodynamic efficiency, and power coefficient could be improved by the selection of appropriate computational methods [3].

D. SAVONIUS ROTOR DIMENSIONS

In the design process, the dimensions of the studied Savonius-rotor have been chosen following to such specifications, while taking into account the cost, the elegance, the simplicity, the feasibility and the durability. It's real dimensions are mentioned in Table 1 and Fig.2. [1]

Height	Diameter (D)	Blade Thickness	Distance e	Distance Ratio	Aspect Ratio
H = 1 m	0.77 m	e_t= 2 mm	e = 60 mm	e/d ≈1/6	H/D =1.29

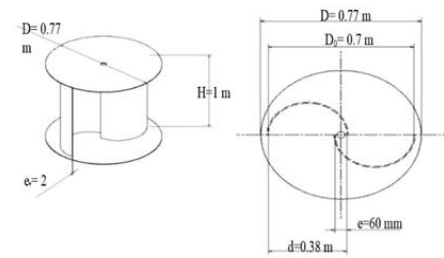

Fig.2.Savonius Rotor [1]

E. MATERIALS SELECTION

Before beginning the construction, we had to select materials with the appropriate dimensions. This would give to our wind turbine reliability, robustness (under critical conditions such as wind gust up to 27 m/s, high temperature, high pressure,…etc), low cost and elegance. The materials that have been used to build the Prototype elements are presented below in the Table 1 [1].

TABLE 1 MATERIALS SELECTION

Stainless Steel ACERINOX ASTM-A-240	Blades, End-blades
Galvanized Steel	PV Support, Base, Side to Side Cylinders
Aluminum	Gearbox

F. ROTOR DYNAMICS [4]

As shown in Fig.3, the tangential velocity (V_t) and normal velocity (V_n) for a VAWT blade can be written as [4]

$V_t = V (\lambda + \cos\theta)$……… (1)

$V_n = V \sin\theta$………. (2)

Where V is the induced velocity and can be assumed to be equal to the freestream wind velocity (V_∞) if there is no flow restriction, $\lambda = \omega R/ V_\infty$ is the tip speed ratio (TSR), θ is the azimuthal angle, and ω is the angular rate and R is the radius of rotor. Thus the effective wind velocity (W) and the angle of attack (α) can be written as

$W = (V^2_t + V^2_n)^{1/2}$………. (3)

$\alpha = \arctan \frac{V_n}{V_t}$ ………. (4)

The airfoil lift coefficient C_L and the drag coefficient C_D are two common parameters to evaluate the aerodynamic performance, which are respectively defined as

$C_L = \frac{L}{\frac{\rho W^2 c}{2}}$ ………. (5)

$C = \frac{D}{\frac{\rho W^2 c}{2}}$ ………. (6)

Where L represents the lift force normal to the effective wind velocity and D represents the drag force tangential to the effective wind velocity. ρ is the density of air. c is the airfoil chord length.

The tangential force coefficient is defined as

$C_t = \frac{F_t}{\frac{\rho W^2 c}{2}}$………. (7)

Where F_t is the tangential force. Furthermore, the tangential force coefficient C_t can be written in terms of the lift and the drag coefficient as [4]

$C_L = C_L \sin\alpha - C_D \cos\alpha$ ………. (8)

The torque coefficient C_T and power coefficient C_P are respectively defined as

$C_T(\theta) = \frac{T}{\frac{\rho AR\,(V_\infty)2}{2}}$ ………. (9)

$C_P(\theta) = \frac{P}{\frac{\rho A\,(V_\infty)3}{2}}$ ………. (10)

Where A is the cross-section area of rotor and for VAWT A= 2R (1). T and P are instantaneous torque and power, respectively, which can be written as

$T = F_t R$ ………. (11)

$P = T\omega$ ……… (12)

Therefore, by associating the above relationships, one can easily obtain

$C_P = \lambda\, C_T$ ………. (13)

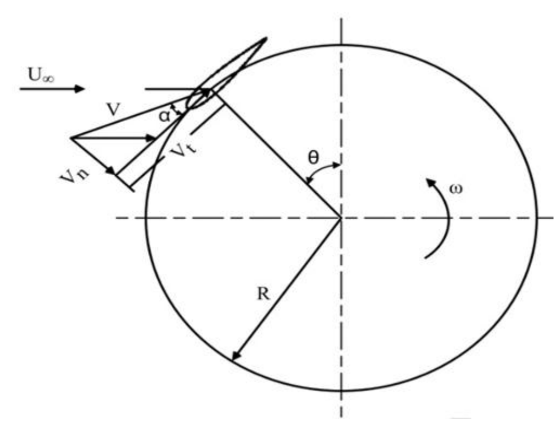

Fig.3. Illustration of the dynamic of motion for a vertical axis wind turbine[4]

G. PERMANENT MAGNETIC BEARING FOR A VERTICAL AXIS WIND TURBINE

Based on the numerical analysis, the permanent magnetic bearing in the configuration 1 with an air gap of 7.5 mm is fabricated for the Vertical axis wind turbine. The schematic arrangement of the PMB used in the vertical axis wind turbine is shown in Fig.5. It consists of an inner neodymium ring magnet concentrically placed in the outer ferrite ring magnet. The outer ferrite ring magnet is supported by the guiding sleeve. The shaft of the turbine is fixed in the inner magnetic ring. These PMBs are basically unstable because according to Earnshaw's when all the six degrees of freedom are freely allowed to move without any constraint, then the system becomes unstable. So, this stability problem in the PMB can be overcome by giving constraint in the axial direction and other five degrees of freedom is allowed to be in free magnetized state. This constraint in the axial movement is accomplished by using a carbide tip sharp point, as shown in Fig.5, for its ease of assembly. The friction introduced by the carbide tip sharp edge is reduced by the axial repulsion of the PMB so that the force on the carbide tip edge is further reduced. This permanent magnetic bearing is installed in the vertical axis wind turbine. The experiment has been conducted on the turbine for different low rated wind velocities. The wind is artificially generated by using the axial fan in the laboratory. For different wind velocity, speed of the turbine is measured with and without permanent magnetic bearing as given in the Table 2. It is observed that the speed of the turbine with the PMB is almost 3 to 4 times higher than the speed of the turbine without PMB. Furthermore, the time required for the turbine to get zero RPM after attaining the maximum speed for different velocities is also tabulated in the Table 2. It is observed that there is a threefold increase in rotation time because of using PMB which reduces the frictional resistance [5].

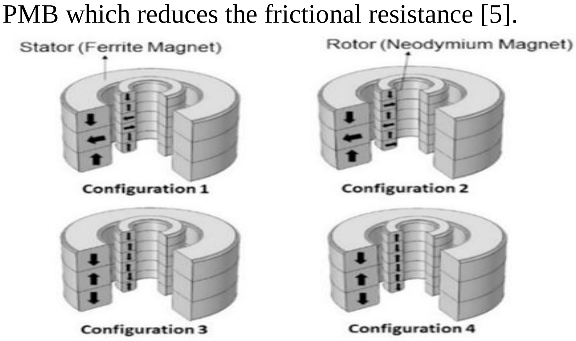

Fig.4. Different configurations of PMB used for analysis[5]

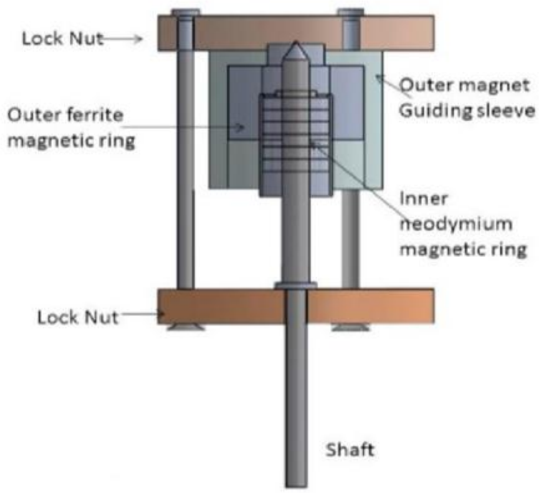

Fig.5. Schematic of a PMB used in vertical axis wind turbine [5]

TABLE 2 EXPERIMENTAL RESULTS WITH AND WITHOUT PMB [5]

Wind Velocity (m/s)	Turbine speed (rpm)		Time required to get zero RPM (Sec)	
	With PMB	without PMB	With PMB	without PMB
3.5	355	83	24.2	8
4	395	103.5	22.3	8.4
4.5	434	124	27.1	8.7
5	474	146	27.3	9.1
5.5	513	168	28	9.3

III. CONCLUSION

This paper presents the study, design and the comparison between the magnetic bearings and simple bearings used in vertical axis wind turbine. Essentially design of blades of turbine is based on savonious type. The aim of the paper is to study the working of vertical axis wind turbine and review the efficiency and effects of savonious type blades. The other reason is to present materials to be used for low cost and elegance. The study shows the efficiency of savonious type blades is more than the other type of blades.

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