POWER GENERATION IN MOVING VEHICLES USING WIND TURBINE

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Abstract - This article focuses on the design of a Diffuser Augmented wind turbine that will be installed on the vehicle to create electrical power that may be utilised to operate accessories or even charge the battery while the vehicle is in motion. The DAWT (Diffuser Augmented Wind Turbine) is designed to be mounted on the roof of the automobile, closer to the windscreen, where the air velocity travelling around the car is at its maximum due to its aerodynamic nature. The horizontal axis diffuser augmented wind turbine is used for this type of design, which may provide a larger power output than conventional turbines. The torque necessary to rotate the rotor is created by the air velocity when the automobile starts moving. The support for the turbine is termed a shroud or diffuser. The car's speed is estimated to be 80kmph (22.2m/s) for the purpose of design.

Key Words: **Diffuser Augmented Wind Turbine, Electric Vehicles, Power Generation.**

1. INTRODUCTION

In the present world fossil fuels are considered as dominant energy sources for both the transportation sector and power generation industries. The reduction of fossil fuel gives a wake-up call for finding alternative energy sources for these sectors. Although, burning fossil fuels produces greenhouse gases (GHGs) which highly influence world climate change. The promising solution for the transportation sector is electric vehicles (EVs) and they are taking a remarkable pace in the vehicle market. It is predicted by the economic studies that EVs will completely take over IC engines in the future. Though the EVs produce less range and should be charged hours for the next run, the electrification of the transportation sector is one of the feasible solutions to the problems such as energy security, global climate change, and geopolitical concerns on the availability of fossil fuels [1].

In a complete life cycle of a car, electric vehicles emit two times less carbon dioxide (CO2) in comparison to diesel engines considering the European electricity mix. The Belgian electricity mix could even make this four times less. The emissions of Carbon dioxide could be further reduced by more than 10 times. if cars were driving on sustainable electricity. Taking about availability and demand of electricity there will be only 1.4% additional demand for power If 10% of our fleet becomes electric. But considering the gearing up of renewable energies and their implementation, the production and supply will only increase [2].

Among renewable energy, solar energy is the predominant one. After solar power, wind turbines are popular and widely used in the locations where the wind resource is highly available. Harvesting Wind energy is those generating electricity from the wind's kinetic energy using wind turbines consisting of rotor blades and hub [3].

This paper will concentrate on the combination of both the EVs and Wind turbine technologies to improve the range of the electric vehicles by placing the turbine on top of the car near the windshield. By using working principle of turbine, the electricity when the car is in motion. Here the electricity produced is stored in the alternator that is used to run the car for extra range or can be connected directly to power the accessories. The materials required and design for the model is discussed in the further chapter.

2. LITERATURE REVIEW

I Electric Vehicles

A vehicle that is propelled by one or more electric motors or traction motors is known as an electric vehicle (EV). An electric vehicle can be self-contained using a battery, solar panels, fuel cells, or an electric generator to convert gasoline to energy, or it can be fueled by electricity from off-vehicle sources via a collector [1].

II History of EVs:

The electric car has been around for over a century and has a fascinating development history that continues to this day. In the late 1860s, France and England were the first countries to create the electric automobile [2].

The first commercial application, a fleet of New York City taxis, was founded in 1897. Early electric vehicles, such as the Wood's Phaeton from 1902, were essentially electrified horseless carriages and surreys. It has been developed since the invention of the electric car till now. Despite this, the major difficulty of their limited driving range persists [2].

III Major components of EV:

Traction Battery:

The battery in an electric automobile serves as a storage mechanism for electrical energy in the form of direct-current power (DC).

Power Invertor:

The inverter converts direct current (DC) from the battery to alternating current (AC), which is then used by an electric motor.

Electric Motor:

The electric traction motors will turn the gearbox and wheels because the controller receives electrical power from the traction battery.

Charger:

Charger is a device that charges batteries. External sources of electricity, such as the utility grid or solar power plants, are used to power chargers. AC power is converted to DC power, which is then stored in the battery.

Fig 1:Traction battery

Fig 2: Invertor

Fig 3: Electric Motor

Fig 4: Charger

IV Turbine and its types:

Wind turbines, which convert the kinetic energy of the wind into electric energy for consumption, are one solution to the developing world's present power shortage. To recover the kinetic energy of moving air, wind turbines use propeller-like blades that are rotated by the wind. The power is transmitted to a generator via a shaft, which transforms it to electrical energy.

Horizontal-Axis Wind Turbines (HAWT):

HAWTs are the most widely used wind turbine designs today. HAWTs use aerodynamic blades (also known as airfoils) mounted on a rotor that may be positioned upwind or downwind. The largely dominant technology today is the three-bladed HAWT the reduced number of blades theoretically reduces the cost but leads to irregular torque [3].

Vertical-Axis Wind Turbines:

Vertical-axis wind turbines (VAWTs) feature a vertical rotation axis, so they can capture wind from any direction, unlike horizontal wind turbines. The main rotor shaft of vertical axis wind turbines (or VAWTs) is positioned vertically. The turbine does not need to be aimed into the wind to be functional, which is one of the main benefits of this setup [3].

Fig 5: HAWT

Fig 6: VAWT

Diffuser-augmented wind turbine:

A diffuser-augmented wind turbine (DAWT) is a wind turbine that has been modified to include a cone-shaped wind diffuser to improve the efficiency of converting wind energy to electricity. The enhanced efficiency is made possible by the diffuser's ability to deliver higher wind speeds. The rotor blades of a DAWT are positioned within the diffuser, which is subsequently put on the support tower's top.

To achieve the higher air velocity, the diffuser's exit hole must be bigger than the entry hole in order to effectively distribute the air. When wind passes through the diffuser, it travels along the walls, causing the wind to generate low pressure zone as it exits [5].

Fig 7: DAWT

3. OBJECTIVES

- The aim of the project is to develop a Power source from moving vehicles using wind turbines.
- To make the device simple and to implement on the electric vehicles to increase the range.

- The objective of this project is to design a prototype that can generate and store energy for later usage.
- To make it eco-friendly and to attain requirements for market availability.

4. METHODOLOGY

I Materials Used:

4.1.1 Diffuser:

The diffuser, also known as the shroud, is a structure installed on the top of the vehicle that supports the turbine and other components that create electricity while the vehicle is moving.

According to Phillips D G (2006), a diffuser with an Exit-Area-Ratio (EAR) of 2.22 and an overall length to diameter metre (L/D) of 0.35 may achieve a 1.38 augmentation [6].

From Research conducted by Balasem Abdulameer Jabbar Al-Quraishi he proved that for rotor diameter of less than 150mm the proposed inlet diameter of the diffuser is 320mm to 350mm. For cost reduction and to increase the efficiency of the power using the same value for further development.

To find the exit diameter of the shroud from the equation

EAR (Exit-Area Ratio) $=\frac{Area_{out}}{Area_{in}}$ ---(1)

Where $Area_{out} = \frac{\pi D^2{}_o}{4}$ ---(2)

$Area_{in} = \frac{\pi D^2{}_i}{4}$ ---(3)

$$Area_{in} = \frac{\pi * 0.32^2}{4} = 0.0804m^2$$

EAR=2.22 applying in equation (1) we get

$Area_{out}$=EAR * $Area_{in}$

$Area_{out}$=2.22 * 0.0804 =0.1784 m^2

From equation (2) applying $Area_{out}$=0.1784 we get

$$Dia_{out} = \sqrt{\frac{4 * Area_{out}}{\pi}} = 0.476m$$

The diffuser is therefore having an inlet and outlet diameters of 320 mm and 476 mm respectively. The length of the diffuser is taken to be 600 mm (from flange angle analysis) for it to cover the whole span of the turbine.

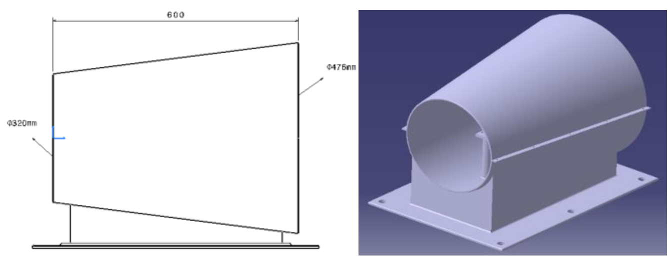


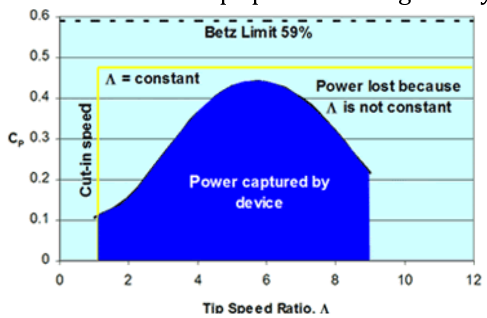
Fig 8: Diffuser

Power Calculations:

Assumptions made for calculation:

- Assuming wind velocity is zero (still air) and considering the velocity of air as vehicle's velocity.
- Density of air (1.225 kg/m3) standard value.
- For design's sake car speed (80kmph or 22.22 m/s) is assumed.

In wind turbine design, the Tip Speed Ratio (TSR) is a critical element. The tip speed ratio is calculated by dividing the speed of the turbine blade tips by the wind speed. The maximum tip speed ratio is given by:



Graph 1: Tip speed Ratio vs Power Coeff

$\lambda = \frac{4 * \pi}{B}$ where B is the number of blades. (i.e., 3)

λ=4.189

From graph we get $C_p \cong 0.38$

To Find Shaft power:

Shaft power coeff= Power coeff + Augmentation factor

$C_{ps} = 0.38 + 1.38 = 1.76$ where Cps is the shaft power coefficient.

Shaft power (Ps)=$\frac{1}{2} * C_{ps} * \rho * A * V^3$,

Where KE= $\frac{1}{2} * \rho * A * V^3$, m= $\rho * A * V$

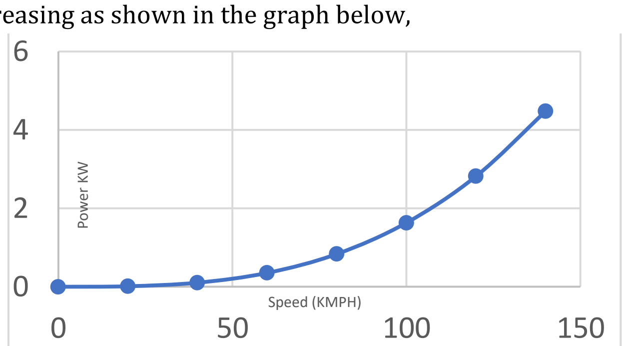
For different values of rotor power produced in the shaft varies for this design purpose considering velocity as 22.22 m/s and dia of rotor as 0.3m we get,

Area=$\frac{\pi * D^2}{4}$= $0.0706m^2$

P_s= $\frac{1}{2} * 1.76 * 1.225 * 0.0706 * 22.22^3$

P_s=0.843 KW

Hence the speed increases the power produced in shaft is increasing as shown in the graph below,



Graph 2: Speed vs Power

4.1.2 Rotor:

The rotor catches the kinetic energy of the wind and converts it into rotational motion. The rotor is made up of three blades and a hub that spins around a horizontal axis at a pace controlled by the wind speed [8].

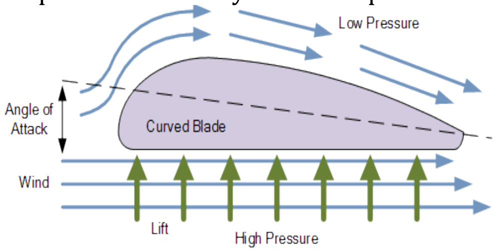


Fig 9: Rotor Blade

Torque on Rotor:

Torque=$\frac{Shaft\ Power(Ps)}{Angular\ Velocity(\omega)}$

Where $\omega=\frac{Tip\ speed\ ratio(\lambda)*Velocity(V)}{Radius\ of\ Rotor(R)}=\frac{4.18*22.22}{0.15}=620\ \frac{rad}{sec}$

Torque produced = $\frac{834}{620}$= 1.34 N-m

Rotor Design:

$\theta=tan^{-1}(\frac{\pi*R*N}{V})$

Where N=$\frac{60*\lambda*V}{2*\pi*R}=\frac{60*4.189*22.22}{2*\pi*0.15}$=5925rpm

$\theta=tan^{-1}(\frac{\pi*0.15*5925}{22.22})$=89.5°

Lift or down force: Every object moving through the air generates either a lifting or a downward force. Down force is similar to the lift experienced by aero plane wings, with the exception that it acts to press down rather than lift up.

Lift Force=$\frac{1}{2}C_L\rho\ V^2A_t$

Drag Force: Some energy is lost in the process of moving the car through the air, and this energy is then employed to overcome a drag force. Drag in vehicles is caused by frontal pressure and rear vacuum [9].

Drag Force= $\frac{1}{2}C_D\rho\ V^2A_t$

From Catia V5 the surface area of Blade is=0.0148 m^2

From Design foil DEMO program for altitude 1.58m and angle of attack 15° C_L=2.03 C_D=0.0297 Where F_L=9.085 N and F_D=0.132 N

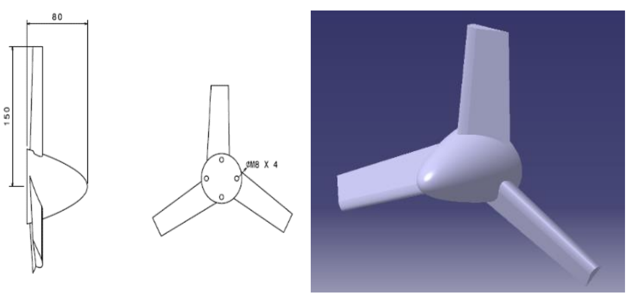


Fig 10: Rotor

4.1.3 Generator

The concept makes use of a high-speed brushless alternator. This is due to the fact that it has fewer moving components. As a result, there is less wear and hence a longer lifespan. Brushless generators are quieter than brushed generators and operate more smoothly [10].

4.1.4 Main Bearing

The main bearing supports the main shaft and transmits the reactions from the rotor loads to the supports on the shroud. On account of the relatively large thrust (axial) and radial loads in the main shaft and the high speed involved, the spherical roller bearing is often used.

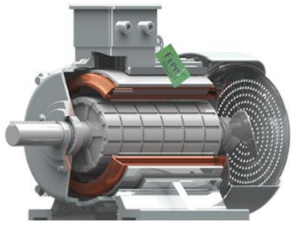


Fig 11: Generator


Fig 12: Bearing

4.1.5 Main Shaft

The main shaft delivers the rotor's rotational energy to the generator via the main bearing. In addition to the rotor's aerodynamic stresses, the main shaft is subjected to gravity loads and responses from the main bearings and generator shaft [12].

A_t=0.01479 (Surface area of blade calculated from CATIA)

$F_L = \frac{1}{2} * 2.034 * 1.225 * 22.22^2 * 0.01479 = 18.69N$

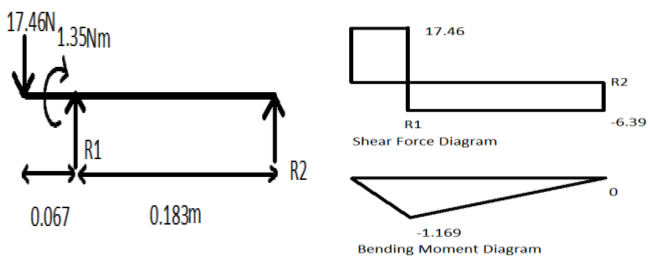
$F_D = \frac{1}{2} * 0.0297 * 1.225 * 22.22^2 * 0.01479 = 0.132N$

F= F_L Cos (90-Ø) - F_D Sin (90-Ø)

F= 18.69* Cos (90-89.5) – 0.132 * Sin (90-89.5) =18.69N

Total thrust F=18.69N Total thrust on all three blades =18.69 * 3=56.07N

The main loadings on the main shaft are the torque on the rotor, and the weight of the rotor blades and hob. So, considering FOS as 3 for safer design any material with more than 170MPa can be used for this design [11].



From the diagram the max shear force and bending moment is 17.46N and 1.169Nm

Taking Factor of safety=3, K_f and K_{fs} are stress concentration factor and shear modification factor, K_b is Size modification factor

S_e^1=endurance Limit and S_e = Endurance limit at critical location.

$K_a = aS_{ut}^b = 57.7 * 170^{-0.718} = 1.2$ and K_b =0.9 for hot rolled materials.

S_e = 1.4 * 0.9 * 0.5 * 170 = 107MPa

By using DE-Goodman's criterion for shaft design:

$$d=\left\{\frac{16*n}{\pi}\left[\frac{(2*Kf*M)^2}{Se}+\frac{[3(Kfs*T)^2)^{0.5}]}{Sut}\right]\right\}^{\frac{1}{3}}$$

$$d=\left\{\frac{16*3}{\pi}\left[\frac{(2*1.7*1.169)^2}{107*10^6}+\frac{[3(1.5*1.35)^2)^{0.5}]}{170*10^6}\right]\right\}^{\frac{1}{3}}= 13.7mm$$

Selecting the standard shaft design as 16mm for the shaft.

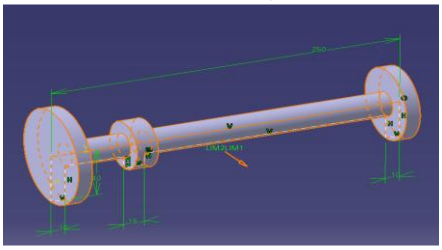


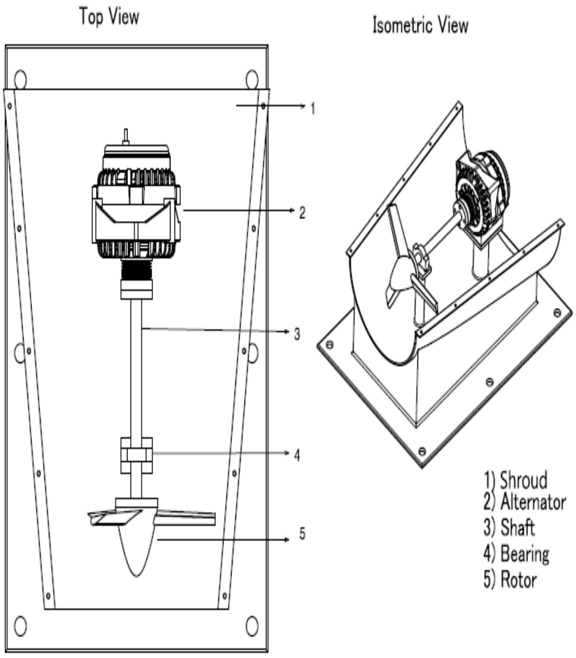
Fig 13: Shaft

Power Produced at end of shaft by considering 24V, 7000 rpm with the power output of 6.66KW is used here with efficiency of 80% [14].

$P_e=\eta_e * \eta_g * P_s$ = 1 *0.8 * 0.843KW=0.6744KW

II Proposed Model

4.2.1 CAD model:



4.2.2 Advantage of Proposed model:

- Range of the vehicle is increased.
- Since the DAWT is used the aerodynamics of the vehicle is not affected.
- More efficiency compared to other traditional models.

5. RESULT & OBSERVATIONS

Renewable energy, particularly wind energy, should be dramatically developed in the next decades to reduce fossil fuel reliance. This may be accomplished by placing turbines in locations where they can efficiently generate maximum energy, such as this project. This project is meant to produce the most energy while taking into account all required design aspects in order to keep costs low. The use of materials that are very robust, fatigue resistant, and damage tolerant are the essential criteria for completing this project. In the previous chapter, it is discussed that the power produced at end of the shaft is 0.6744KW at the speed of 80KMPH (22.22m/s). This can be further increased by the additional research on the materials and using the efficient materials that can serve the purpose.

6. CONCLUSION AND FUTURE SCOPE

With sophisticated communication, control, and metering technology, the study found that the deployment of Moving Vehicles into Power Generation would be viable. The interoperability of EVs for power generation will be aided by wind turbines in this scenario. Although more research is required on the incorporate the design of turbines into the body of the car.

Further execution of the project may be done by enhancing the project's aerodynamics by finding a more efficient location for the turbine. In order to create more energy, more turbines can be installed, with one possibility being to place the turbine under the bonnet, where air can reach the turbine through the radiator gap. EVs and rear-engine automobiles are both capable of this. With advancements in technology, it will be feasible to expand the size of the blades in the future, allowing for increased power generation and vehicle range.

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