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Vertical wind mill based upon moving vehicle on national highways

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ABSTRACT

This paper presents the effective approach to harness electrical energy from the highways by means of vertical axis wind turbine. The wind turbine consists of stationary shaft which is mounted on the ball bearing on top and bottom end of the shaft. In addition, dynamo is connected to upper and lower part of the wind turbine. As the vehicles are moving at faster rate on two different directions in highways, the wind turbine, which is placed on the highways sides, is able to rotate effectively on its own axis in any of the direction. As a result, the large amount of electrical energy gets generated in both day and night time. This wind power generation is an alternative way for power generation instead of depleting non-renewable energy sources.

Introduction

Today the world runs on a platform of energy sources that will not be available forever. So, it is important to understand and find ways to create energy from sources that are free and constant. We have one way harnessing the energy of the wind and converting it into electricity. This is the basic principle on which windmills work. At present days, most of the windmills are occupying lot of lands for installing them. In order to compensate the spacing occupied by the windmills, Vertical axis turbines are rarely found with the curvy blades shape. As long as the wind blows, the turbine blades are rotating by which the generator, which is connected to the blades, generates electricity. This electricity is then run through wires that lead directly into the buildings where the electricity is needed. Smart windmills can generate about 1000 watts of energy and are sometimes used for power farms and other homes. Larger turbines can generate many megawatts of energy. If the vehicle is passing at about 20km/hr, wind acts upon the windmill to operate the turbine-generator set for generating power. It is very convenient way to generate electrical energy by means of using windmills on the road sides. Also the proposed system provides safer operation, simple installation and less maintenance.

Literature survey

Gerald muller et al [1] discussed about the vertical axis and horizontal axis machines integration of small scale turbine. It is clearly explained by vertical axis resistance type method.

Davood saeidi et al [3] explains the different types of vertical axis wind mill. The wind turbines can be generally divided into three types such as savoniustype, darrieus types and rotor types. Although it is discussed the curved blade and straight blade type usage and its feature.

Proposed system implementation terminology

The vertical axis turbine can run in a small amount of velocity [1]. The wind mill is directly connected by gear box and wings (sails).so the wind flow is passing through sails, in which oscillates by few seconds.

Smart wind power is the conversion of wind energy into useful form of energy such as electric energy by using wind turbines in the middle or either sides of the highways to generate electricity.

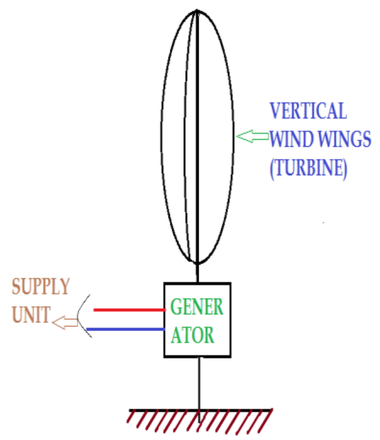

Fig.1 Schematic diagram of proposed system

Wind power is an alternate to fossil fuels which is plentiful and renewable widely [9]. Clean energy produces no greenhouse gases during its operation and requires little space. So, we suggest that the energy can be harnessed in highways or roadways by placing the smart wind turbine in the middle of the highways. The smart wind turbine rotates more effectively because of the wind power generated in the roadways due to large number of vehicles passing at very high speed. The smart wind turbine consists of the shaft which is mounted on the blades and the bottom end is connected to the generator. When the wind power increases certainly the number of rotations gets increased. So we can get large amount of electricity for domestic purposes. In this overall cost per unit of energy produced is less than the cost of coal, natural gas and its installation. So the implementation can be made easier than any other methods. Main parts of a vertical wind turbine are rotor shaft arranged vertically, vertical wind generator placed near the ground, gearbox also placed near the ground and blades generally three or four in number.

Vertical Axis Wind Turbines (VAWT)

This type of wind turbine where the main rotor shaft is set vertically and the main components are located at the base of the turbine. Drag-type VAWTs, such as the savonius rotor, typically operate at lower Tip Speed Ratios (TSR) than lift-based VAWTs

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such as darrieus rotors and cyclo turbines. A unique, mixed darrieus - savonius VAWT type has recently been developed and patented i.e. Curved type blade. The main benefits obtained are improved performance at lower wind speeds and a lower rpm. Regime at higher wind speeds resulting in a silent turbine suitable for residential environments.

Generator

An electric generator is a device that converts mechanical energy to electrical energy. The source of mechanical energy may be a reciprocating or turbine steam engine, water falling through a turbine or waterwheel, an internal combustion engine, a wind turbine, a hand crank, compressed air or any other source of mechanical energy.

Gearbox

One of the most important main components in the wind turbine is the gearbox [6]. Placed between the main shaft and the generator, its task is to increase the slow rotational speed of the rotor blades to the generator rotation speed of 1000 or 1500 revolutions per minute (rpm).

Software implementation of proposed terminology

Wind Power Analysis

Wind is made up of moving air molecules which have mass - though not a lot. Any moving object with mass carries kinetic energy in an amount which is given by the equation:

$$kn = 0.5 \times m \times v^2 (joules) \quad (1)$$

the mass is measured in kg, the velocity in m/s and the kinetic energy is given in joules.

Air has a known density (around 1.23 kg/m3 at sea level), so the mass of air hitting our wind turbine (which sweeps a known area) each second is given by the following equation:

$$m = A \times \rho \times v_a \left(\frac{kg}{sec}\right) \quad (2)$$

Therefore, the power coefficient (i.e. Energy per second) in the wind hitting a wind turbine with a certain swept area is given by simply inserting the mass per second calculation into the standard kinetic energy equation given above resulting in the following vital equation:

$$p_{co} = 0.5 \times A \times \rho \times v_a^3 (watts) \quad (3)$$

Every type of rotor has a unique power coefficient curve. The reason for the shape of the curve is that the optimum P_{co} occurs when the rotor blades are operating at their maximum lift drag ratio. At a higher than optimum TSR, they produce less than their maximum lift because the angle of incidence decreases. At runaway speed, the angle of incidence approaches zero, and lift and drag force balance, so the shaft power is produced that the efficiency once again is zero.

Table 1. TSR versus Blade

TSR	Number of Blades
3	3-8
4	3-5
8-15	1-2

Here, if the characteristics of both the load and the rotor torque are known the system performance. Torque coefficient is defined as

$$C_T = T \div T_{max} \text{ (NM)} \quad (4)$$

T is the shaft torque, and T_{max} is Torque at maximum efficiency.

At this stage no attempt is made to analyse angular momentum exchange between the air and the turbine. However, it is obvious that if the turbine turns one ways the air must turn the other, and full analysis must eventually consider the vortices of air circulating downwind of turbine.

The maximum conceivable toque t on a turbine rotor would occur if the maximum stress could somehow be applied at the blade tip furthest from the axis. For a propeller turbine wing of Radius (R)

$$T_{max} = F_{max} \times R \text{ (NM)} \quad (5)$$

$$F_{max} = 0.5 \times \rho \times A \times R \times v_a^2 \quad (6)$$

For a working machine producing a shaft torque t, the torque coefficient C_T .Refer to “(4)”,

$$T = C_T \times T_{max} \text{ (NM)} \quad (7)$$

(NM is the unit Newton meter)

We know TSR is defined as the ratio of the outer blade tip speed to the unperturbed wind speed.

$$TSR = (R \times \omega) \div \rho \quad (8)$$

Where R is the outer blade radius and

W is the rotational frequency

Refer to “(8)”, we can found the rotational frequency (ω)

$$\omega = (TSR \times v_a) \div R \text{ (Hz)} \quad (9)$$

The shaft power is the power derived from the turbine P_t,

$$P_t = C_T \times T_{max} \times \omega \text{ (watts)} \quad (10)$$

CFD analysis

Computational Fluid Dynamics (CFD) is one of the branches of fluid mechanics that uses numerical methods and algorithms to solve and analyse problems that involve fluid flows. Computers are used to simulate the interaction of liquids and gases with surfaces defined by boundary conditions. Even with high-speed supercomputers only approximate solutions can be achieved in many cases.

The pre-processing will include cad-cleaning and mesh generating. To be able to generate a

Aerodynamic devices work equally well at all speeds are 20% reduction in aerodynamic drag generates 6% fuel economy improvement at 30mph, 10% fuel economy improvement at 50mph, 14% fuel economy improvement at 80mph.

Theory of aerodynamics

In this section [3], the fundamental of aerodynamics is discussed to gain understanding in doing analysis of the paper [5]. The basics equation and terms in aerodynamics field or fundamental of fluid mechanics such as bernoulli’s equation, lift and drag coefficient, boundary layer, separation flow, and shape dependence are studied.

Bernoulli’s equation

Aerodynamics play main role to defined road vehicle’s characteristic like handling, noise, performance and fuel economy. The improvement on the characteristic related through the drag force which is ruled by bernoulli’s equation.

$$P + 0.5 \times p \times v^2 = constant \quad (11)$$

The bernoulli’s equation from equation gives the important result which is;

Static pressure + dynamic pressure = stagnation pressure.

Lift and drag coefficient

The main two perspectives of aerodynamics forces. The first force is pressure distributions that normal (perpendicular) force to the body which is will produce pressure, drag and lift coefficient. The second force is shearing force that tangential (parallel) to the surface of body’s vehicle.

Drag coefficient

As was informed before the net drag is produced by both pressure and shear forces, thus the drag coefficient (C_D) for a vehicle body can be defined as:

$$C_\downarrow D = D \div (0.5 \times V_\downarrow \mathbf{inf}^\uparrow 2 \times P_\downarrow a) \quad (12)$$

Lift coefficient

The lift force can be determined if the distribution of dynamic pressure and shear force on the entire body are known. Therefore the lift coefficient (C_L) is given by,

$$C_L = L \div (0.5 \times V_{inf}^{2} \times P_a) \qquad (13)$$

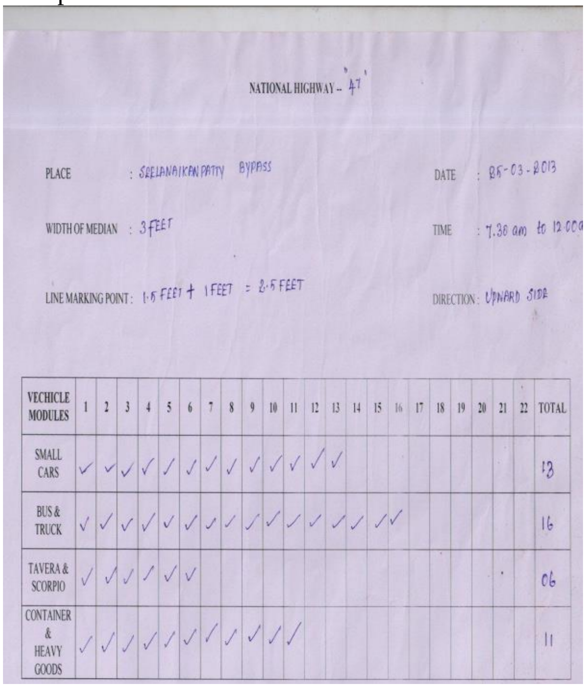
Boundary layer

Boundary layer study in aerodynamics can be described on a flat plate where is develop with two types flow which is laminar and turbulent flow[10]. Due to fluid viscosity, a thin layer will exist when the velocity parallel to the static flat plate and then gradually increase the outer velocity.

The thickness of boundary layer also increases with the distance along the flat plate's surface.

Case study analysis

In this case study is taken by the national highways, in which how much vehicle passing along the roadways. In their time wind mill capturing air to delivered output power. This survey is taken by the Salem highway time duration is 4.30 hours and passed 46 vehicles.



NATIONAL HIGHWAY – '47'

PLACE : SEELANAIKANPATTY BYPASS

DATE : 25-03-2013

WIDTH OF MEDIAN : 3 FEET

TIME : 7.30 am to 12.00

LINE MARKING POINT : 1.5 FEET + 1 FEET = 2.5 FEET

DIRECTION : UPWARD SIDE

VECHICLE MODULES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	TOTAL
SMALL CARS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓										13
BUS & TRUCK	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓							16
TAVERA & SCORPIO	✓	✓	✓	✓	✓	✓																	06
CONTAINER & HEAVY GOODS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓												11

Fig 2. Case study survey details

Result and analysis

Car analysis

In the analysis, velocity of the wind is depends upon the shape of the vehicle. In fig.no.4 the air flow passing through the car is 16.667m/sec. Air flow is convert from m/sec into km/hr. The result of the conversion is 60km/hr. The maximum (full) velocity attains by red colour point, the middle velocity is yellow colour point, and the minimum velocity is blue colour.

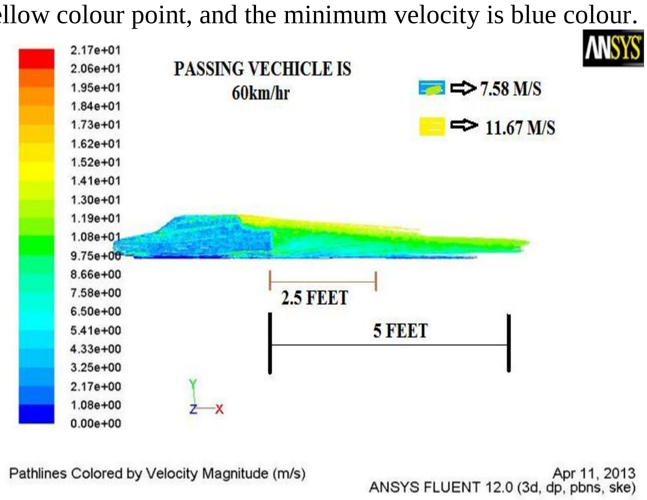


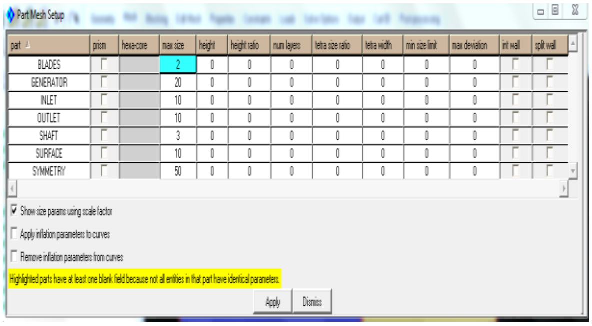
Fig 3. Velocity of car analysis for 60 km/hr

The analysis of the vehicle model is done in CFD tool. The car model drawn in software. In figure.3, the dimension of the car is3m, width of the car is 1.5m, and the height of the car is1.5m. In this methodology, the car model is executed by iteration process. The number of iteration obtained is 21steps. The data which is obtained only at 21st step (16.667m/sec). The maximum air flow is get from the back side top corner of the car and the minimum air flow is get from the bottom of the car, which is not use. Because the height of the median is higher than bottom position of car.

Wind mill analysis

Minimum velocity of wind mill

In fig.5, in which ansys for noted by blades, generator, shaft, surface are required[8]. The air flow of car in which passes through the point is 4.5m/sec. Then the revolution speed of the blade is 3.16e-01 to 6.36e0m/sec.



Part Mesh Setup

part	prism	hexa-core	max size	height	height ratio	num layers	tetra size ratio	tetra width	min size limit	max deviation	int wall	split wall
BLADES	☐		2	0	0	0	0	0	0	0	☐	☐
GENERATOR	☐		20	0	0	0	0	0	0	0	☐	☐
INLET	☐		10	0	0	0	0	0	0	0	☐	☐
OUTLET	☐		10	0	0	0	0	0	0	0	☐	☐
SHAFT	☐		3	0	0	0	0	0	0	0	☐	☐
SURFACE	☐		10	0	0	0	0	0	0	0	☐	☐
SYMMETRY	☐		50	0	0	0	0	0	0	0	☐	☐

☑ Show size params using scale factor

☐ Apply inflation parameters to curves

☐ Remove inflation parameters from curves

Highlighted parts have at least one blank field because not all entities in that part have identical parameters.

Apply Dismiss

Fig 4. Wind flow analysis model table

The design of generator and blade wings, width of generator outside is 1.8feet, height of generator is 2 feet, length of the generator is 1.5 feet, the shaft of generator is 0.5 mm thickness and its diameter is 5m, thickness of wing is 0.3mm, radius of wings blade is 15cm, height of the blade is 90cm.the ansys in which pass the air to the distance of 3feet from wind mill. Wings blades are rotate freely at which analysed atmospheric air impact of wings revolution per seconds.

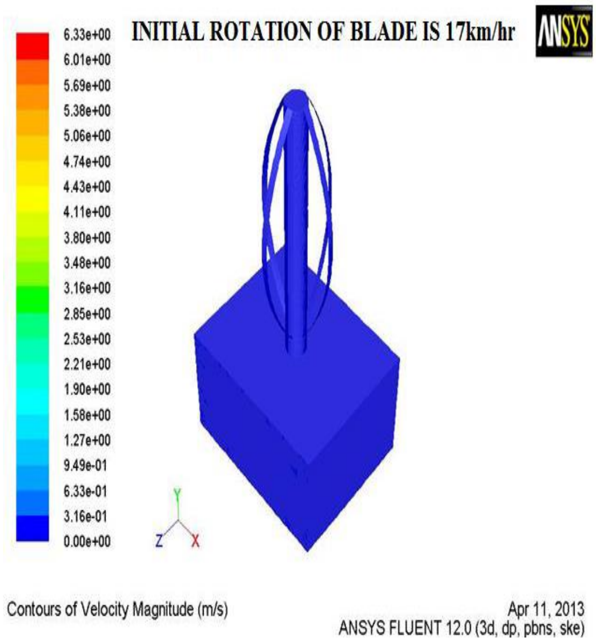


Fig 5. Minimum Velocity of Passing to Rotate Wind Turbine Wings

Maximum velocity of wind mill

The analysis of data, the 148km/hr velocity of air flow the blade does not change the mechanical strength of wings. It applied above the 150km/hr changes or losses mechanical property of the wind wings.

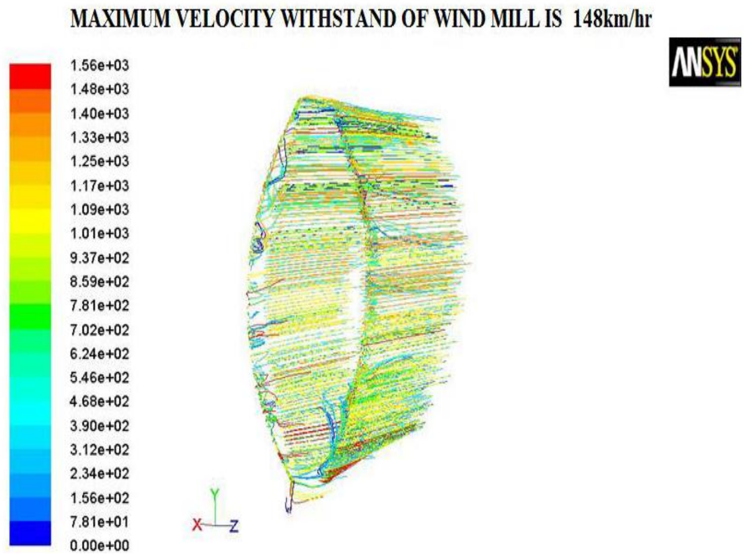


Fig 6. Maximum Velocity of Passing to Lose Mechanical Property of Wind Turbine Wings

Mathcad simulation result

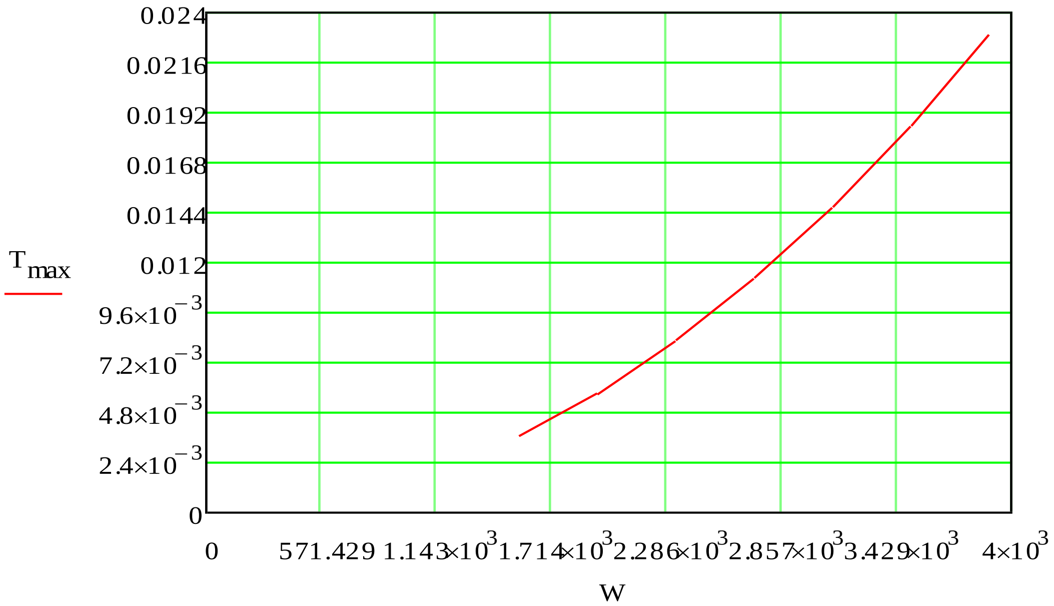


Fig 7. Mechanical Characteristics of Maximum Torque Versus Rotational Frequency

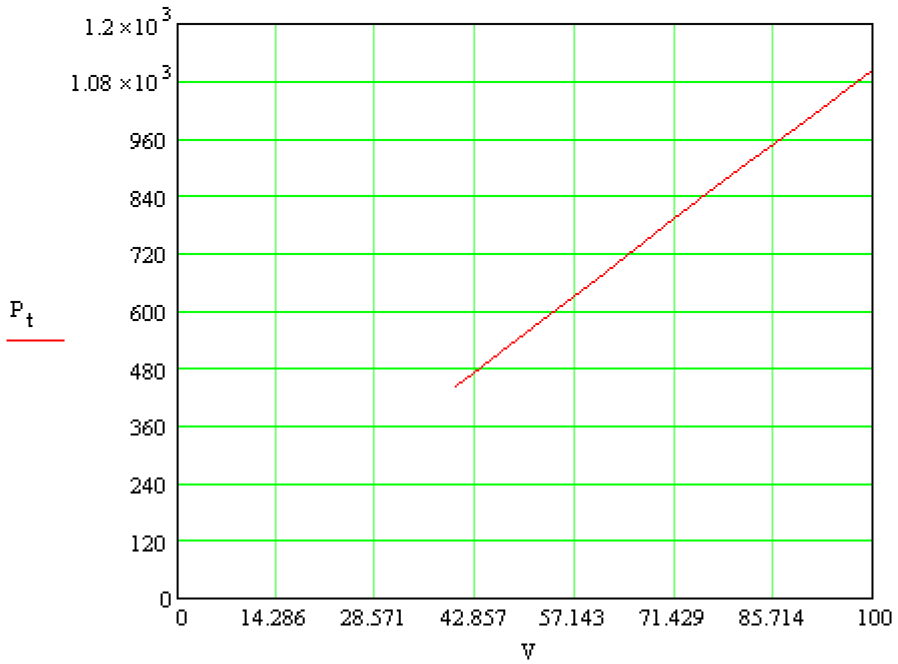


Fig 8. Electrical Characteristics of Velocity (m/s) Versus Turbine Power (Watts)

Applied the force of the output air passing the wings blade is 1.5e03m/sec of wind.

Conclusion

The Vertical-axis wind turbine designed is ideal to be located on national highways to generate electricity, powered by wind. The elevated altitude gives it an advantage for more wind opportunity. Vertical axis wind energy conversion systems are practical and potentially very contributive to the production of clean renewable electricity from the wind even under less than ideal sitting conditions. With this idea, it is sure that the nation will empower the electrical energy on national highways.

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