Design and Simulation of Wind Turbine on Rail Coach for Power Generation

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Abstract-- **Energy resources in our modern fast paced techno world are fast depleting. Hence a renewable energy source is much required at the moment. Wind energy is a renewable source of energy. today, the output power from wind turbines can be utilized in two ways, either by direct use of the mechanical shaft power (through a gearing ratio) or by letting the wind turbine power t an electrical generator, and utilizing the generated power as electrical power. This paper brings a new possibility for the utilization of the wind generated power, for various electrical components inside a typical railway train through the batteries ,charged by the wind energy harnessed by a wind turbine mounted at the top of the train coaches. This setup consists of duct, turbine, and generator. The setup is designed in such a way that it does not affect the performance of the train.**

Average velocity is estimated for the train and the suitable specification of generator is selected. The theoretical calculations of duct, turbine and pulley parameters are calculated and the whole setup is designed in CATIA, also by varying the inlet air velocity, the speed and torque of the turbine can be calculated using CFX software. This parameter are used for calculating generator's speed and torque and validated by comparing with the theoretical calculation. Future advancements are discussed, and a path for experimental verification is proposed.

Keywords: Renewable wind energy, Duct, Wind, Wind turbine, Moving train, Rotation, Electricity.

I. INTRODUCTION

In this modern age more and more energy is required for daily consumption in all walk of life. Sources and quantum of fossil energy are dwindling day by day and getting exhausted at a very fast rate. Hence conservation, tapping new sources of energy and harnessing of the same from the various non-conventional sources, is an important aspect of energy production/conservation and utilization all over the world. The sky-rocketing price of crude oil has ruined the economy of many a country, hence there is a crying need for production of energy from non-conventional sources at the earliest. The present concept is one of the answers to this problem, as the said induced wind into useable electric energy which can be utilized straight away or stored in batteries.

This invention relates to a method for generating electricity using high wind pressure generated by fast moving vehicles channeling the induced wind in the direction of the wind turbine. A fast moving vehicle compresses the air in the front of it and pushes the air from its sides thereby creating a vacuum at its rear and its sides as it moves forward.

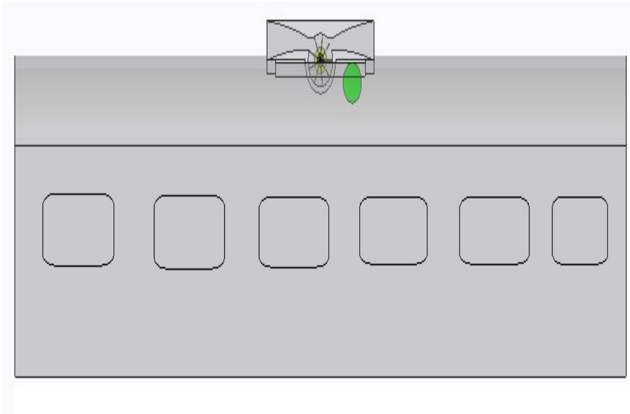

Figure 1: basic setup

The kinetic energy of the wind movement thus created can be used to generate electricity. The moving vehicles encounters wind may be railway trains or airplanes, will sweep off it, in a faster manner making heavy winds. During this, when a wind turbine, if fit to the moving vehicle will generate adequate amount of energy. The air flow will cause turbine to rotate and thus electricity can be produced.

The main object of the present invention is to provide a method and a system for generating electricity using easily available wind induced by moving vehicles/airplanes in transit or in operation. The other object of the invention is to provide a method and a system for generating electricity by using high wind pressure generated by moving vehicles, using this free renewable input namely air and independent of the vagaries of seasonal winds having the variation in direction and wind speeds when they do flow and that too neither at all times or places nor having the necessary force of wind to operate wind mill to generate electricity as required.

Description of Invention

Wind Pressure
↓
Compressed Air
↓
Rotate Turbine
↓
Generate Electricity

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Paper Background

Energy crisis is one of the major problems of India and to overcome this, our government is aspiring in all possible ways. Paucity of electricity has left various parts of the country in darkness. It is the duty of every organization to contribute in overcoming the power crisis. On their part, Indian railway has put forth its effort to generate electricity from wind power in a moving train.

Once, this was a failure project because of improper design and position of the turbine which made it hit on the over bridges and electric lines. The other main reason which made it unrealistic is the drag force which affected the performance of the train. By taking these problems into consideration, we have designed our model to overcome these drawbacks.

II. CONSTRUCTION

Duct

A duct is defined as a tube, pipe or a canal by means of which a substance, especially a fluid or gas is conveyed. Here the duct is designed in such a way that it reduces the drag force and increases the velocity of the air that hits the turbine blades.

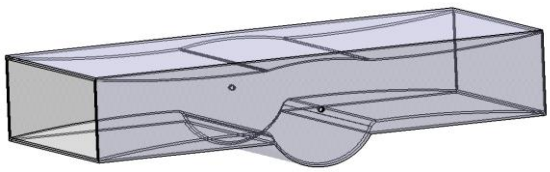

Figure 2: Duct Design

A drag is created due to impulse force created at the sharp edges of the duct. So, to remove this impulse force, the duct is designed with a smooth surface by neglecting the sharp edges all over the path at which the air pass through.

Wind Turbine

A wind turbine is a device that converts kinetic energy from the wind into electrical power. A wind turbine used for charging batteries is widely known as wind charger.

Generator

A generator is a device that converts mechanical energy into electrical energy. Here the generator is coupled with the wind turbine through belt. So, as the turbine rotates, generator also rotates. As the generator rotates, gradually electric current is produced.

Belt

A belt is a loop of flexible material used to mechanically link two or more rotating shafts. Belts may be used as a source of motion to transmit power efficiently or to track relative movement.

Setup

The whole setup which includes a duct, turbine, generator and belt are placed on the hollow place at the roof top. A small portion is made open on the roof for the air to enter into duct. The setup is placed in such a way that it is fitted within the maximum height of the train, so that it does not hit on the over bridges and electric lines on the pathway of the train.

Every coach consists of a single turbine generator setup at its middle portion on the roof. The blade of the turbine is designed by considering the direction of rotation.

Here, the duct and blades are designed symmetrically, so that in whatever direction the wind flows, the blades can rotate and generate electricity.

III. WORKING MODEL

A duct is placed on the roof of the train coach. When the train moves, air enters the duct and the duct is designed in such way that it can reduce the drag force and increase the velocity of the air.Duct is designed like a converging nozzle at the entry side, so the velocity of the air is increased when it reaches the turbine. This high velocity air hits on the blades of the wind turbine. Thus the turbine rotates.

The exit portion of the duct is designed like a diverging nozzle, so that the air gets expanded and cooled and gets into the atmosphere without providing any resistance to the performance of the train. The turbine is connected to the generator with a belt. Thus, as the turbine rotates the generator also rotates which results in generation of electricity. The generated Alternate Current (AC) is converted into Direct Current (DC) with the help of rectifier and this DC current is stored in the battery which can be used for various purposes.

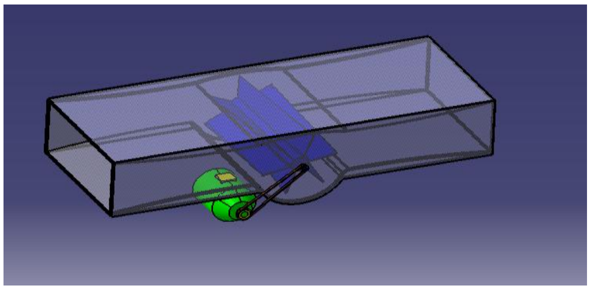

Figure 3: CAD model of the wind turbine

IV. DESIGN PARAMETER

Generator Specifications

RPM	VOLTS	AMPS
150	12	1.5
300	25	4
500	43	7
750	60	10
1000	70	11

Table 1 - Generator specification

Torque 7.35-1.14 N-m

Rated power-0.77 kw

Therefore N_2=1000 rpm is the generator speed

$$\frac{D_1}{D_2} = \frac{N_2}{N_1'}$$

D_1 =60mm

D_2=100mm, Therefore N_1'=1666.67 rpm.

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Actual speed of turbine is
F_b= blade coefficient for variable speed appliances F_b=0.6
N_1'=N_1× F_b =1666.67 rpm
N_1=2777 rpm.

V= $\frac{\pi DN}{60}$ m/s, D= 300mm

V=43.62 m/s (inlet velocity).

Duct Inlet
Considering drag force the duct inlet is designed as small as possible so that it makes maximum use of inflowing air.

The hollow space provided for wiring and piping is 20.2cm.Let the inlet area be (considering drag)

L_1=500mm, B_1 = 240mm

Inlet air velocity = vehicle velocity km/hr.

Vehicle

Velocity (max) = 120km/hr (source railway)

Maximum velocity (v_1) = 120 km/hr. = 33.33m/s

Air inlet velocity (v_1) = 33.33m/s.

Velocity desired at throat (v_2) =44 m/s.

From continuity equation,

$A_1 V_1 = A_2 V_2$

$L_1 \times b_1 \times V_1 = L_2 \times b_2 \times V_2$

500×240×33.33 = 500×b2×44

B_2 =181.8 = 182mm.

Duct Throat Dimensions

L_2 = 500mm

B_2 = 182mm

Torque
P = 2ΠNT/60
0.77= 2×π×1000×T/60
T=7.352 Nm.

Dimensions of Belt
L=Length of the belt.
C=Centre distance of the pulleys.
D=Diameter of generator pulley.
d=Diameter of turbine pulley.
β =Angle of wrap.
θ_a=Angle of wrap of turbine pulley.
θ_b=Angle of wrap of generator pulley.
T_1=Tight side tension.
T_2=Slack side tension.
$L=2c+\frac{\pi}{2}(D+d)+\frac{(D-d)^2}{4c}$
C=2(D+d)
C =2(100+60)
C=320mm

Length of Belt

$L=2\times 320+\frac{\pi}{2}(100+60)+\frac{(100-60)^2}{4\times 320}$
L =892.58mm

$\beta=\theta_a=\pi-2\times SIN^{-1}\frac{(R_a+R_b)}{320}$
$= \pi-2\times SIN^{-1}\frac{(50+30)}{320}$
$=151^o$
$\theta_b=\pi+2\times SIN^{-1}\frac{(R_a+R_b)}{320}$
$= \pi+2\times SIN^{-1}\frac{(50+30)}{320}$
$=209^o$

$\frac{T_1}{T_2}= e^{\mu\beta}$
μ=0.20
$\frac{T_1}{T_2}$=1.58
T_1=1.58T_2

Tight and Slack Side Tension of Belt
T=(T_1-T_2)×R_a
7.352=(1.58T_2-T_2)×30
T_2=422.52 N.

T_1=1.58×T_2
T_1=1.58×845
T_1=667.6 N.

Load of drive 0.75 to 5kw
Belt top width = 13mm
So thickness=8mm

Velocities of the belt drive considering thickness

No slip $V_1 = V_2$

Slip of the belt

$$\frac{N_2}{N_1} = \frac{D_1 + t}{D_2 + t}\,\frac{(1-s)}{100}$$

$$\frac{1000}{1666.66} = \frac{60+8}{100+8}\,\frac{(1-s)}{100}$$

S= 4.7% (for both pulleys)

By substituting the slip for both sides we can get the generator speed

$$\frac{N_2}{N_1} = \frac{D_1}{D_2}\,\frac{(1-S_1)}{100}\,\frac{(1-S_2)}{100}$$

$$\frac{N_2}{1666.66} = \frac{60}{100}\,\frac{(1-4.7\%)}{100}\,\frac{(1-4.7\%)}{100}$$

N_2=908.2 rpm.(Not exceed 1000 rpm)

So Design is safe.

V. RESULTS AND DISCUSSION

By employing ANSYS CFX, flow analysis is done for the wind turbine model and the results are tabulated for different air velocities and the corresponding speed Values of the turbine and generators are calculated.

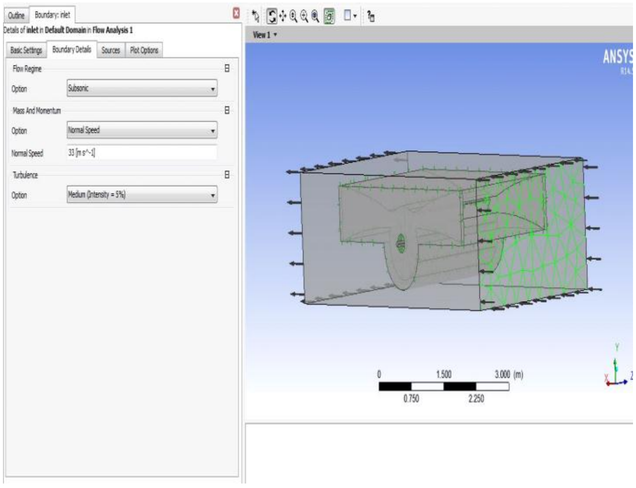

Figure 4: velocity profile of turbine in ANSYS

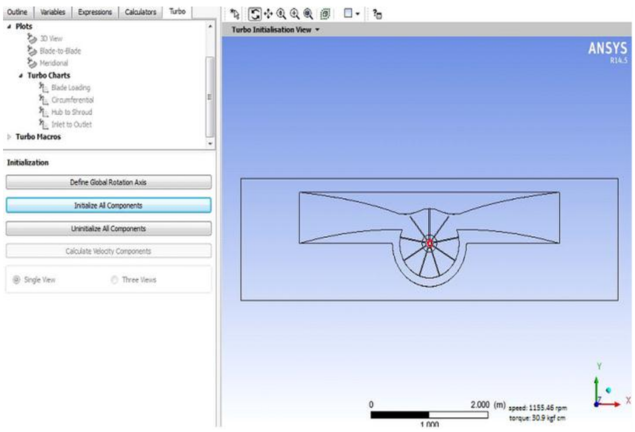

Figure 5: Speed and torque values

S.no.	Air inlet velocity v m/s	Turbine speed N1 rpm	Generator speed N2 rpm	Turbine torque T_1 N-m	Generator torque T_2 N-m
1	33	1555.08	971.92	0.831	1.32
2	32	1497.32	935.82	0.923	1.47
3	26	1225.49	765.93	1.793	2.86
4	25	1155.46	722.16	1.932	3.09
5	15	700.28	437.67	3.380	5.40
6	14	630.25	393.90	0.723	1.17
7	12	560.22	350.13	0.577	0.923

Table 2 Computational approach

S.no.	Air inlet velocity v m/s	Turbine speed N1 rpm	Generator speed N2 rpm
1	33	1666.67	1041
2	32	1604.2	1002
3	26	1336.9	835.5
4	25	1260.5	787.81
5	15	763.94	477.46
6	14	687.54	429.71
7	12	611.15	381.96

Table 3- Theoretical Approach

Therefore computational value of F_b=0.55

m the above tabulation of computational approach it is significant that the velocity of 12m/s i.e. 43.2km/hr. the torque of the generator falls below 1.14 Nm. Therefore the generator is active only at speed range of 43.2km/hr. - 120km/hr. below this speed the device is inactive.

VI. CONCLUSION

This system helps in effectively utilizing the wind energy and generating electrical energy at low cost with less maintenance.

With the Indian railways network of thousands of kilometers running across the length and breadth of our nation, by implementing this system of power generation, we can generate power to supplement the requirements of rail passengers such as audio facilities, Wi-Fi facilities, lighting facilities, etc.

The technology is expected to contribute to the cause of the environment as it helps to reduce carbon emissions and also assists the government in saving on fuel too.

It can be concluded that an effective system can be installed in rail coach to generate power which is purely environment friendly and cost effective.

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