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Feasibility of the Concept of Miniature Windmills on Trains

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Abstract: **Energy crisis has plagued our country for a long time. We are on the lookout for alternative sources of energy. One such alternative form of energy is the Wind Energy. The paper discusses the innovative implication of wind energy for the production of energy for trains. The railways have vastly been burdened with high load demands. The generation of power from wind energy on trains can be implemented by the installation of Miniature Wind Mills at periodic intervals of distance at the roof of the train structure. The energy drawn from the rotation of the blades can be used for lighting and other purposes. The aim of the paper is to critically examine the feasibility of such an installation.**

1. INTRODUCTION

Wind power is the conversion of wind energy into a useful form of energy, such as using wind turbines to produce electrical power, windmills for mechanical power, wind-pumps for water pumping or drainage, or sails to propel ships. Wind power, as an alternative to fossil fuels, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation and uses little land. The effects on the environment are generally less problematic than those from other power sources. As of 2011, Denmark is generating more than a quarter of its electricity from wind and 83 countries around the world are using wind power to supply the electricity grid. In 2010 wind energy production was over 2.5% of total worldwide electricity usage,and growing rapidly at more than 25% per annum. [1]

2. WINDMILL PREREQUISITES

The Wind Power depends on 1) amount of air (volume) 2) speed of air (velocity) 3) mass of air (density) flowing through the area of interest (flux).

The blades convert the kinetic energy in the wind into rotating shaft power to spin a generator that produces electric power.
The rotor blades extract energy from the wind based on

Bernoulli's principle to obtain lift (i.e., due to pressure difference). Since the blade is moving much faster at the tip than near the hub, the blade must be twisted along its length to keep the angles right. Increasing the angle of attack too much can result in a stall. When a wing stalls, the airflow over the top no longer sticks to the surface and the resulting turbulence destroys lift. If more than 3 blades, the turbulence caused by one blade affects the efficiency of the blade that follows. If less than 3 blades, power and torque pulsations will appear at the generator terminals.Three-bladed turbines show smoother and quieter operation, with minimum aerodynamic interference.[2]

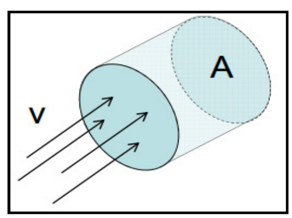
Kinetic Energy definition: $KE = ½*m*v^2$

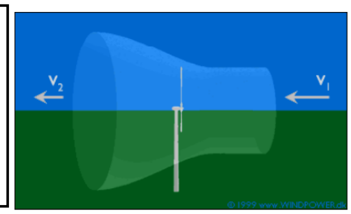
Power is KE per unit time: $P = 1/2*(d(m)/dt)*v^2$

Fluid mechanics gives mass flow rate (density * volume flux): $dm/dt = \rho * A * v$

Thus $P = 1/2 * \rho * A * v^2$

This implies that the power produced is proportional to the cube of velocity, the air density and the rotor swept area $A = \pi * r^2$

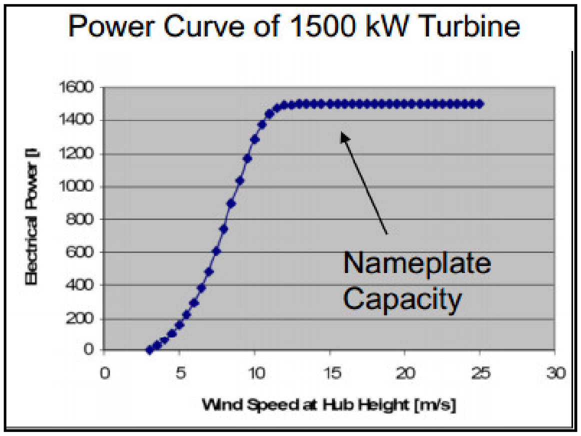




Betz's law calculates the maximum power that can be extracted from the wind, independent of the design of a wind turbine in open flow. According to Betz's law, no turbine can capture more than 16/27 (59.3%) of the kinetic energy in wind. The factor 16/27 (0.593) is known as Betz's coefficient. Practical utility-scale wind turbines achieve at peak 75% to 80% of the Betz limit.

The Power Coefficient, Cp, is the ratio of power extracted by the turbine to the total contained in the wind resource $Cp = P_T/P_W$.

Finally we get the Turbine power output as
$P_T = 1/2 * \rho * A * v^3 * C_P$.
The Power Curve of Wind Turbine [3]

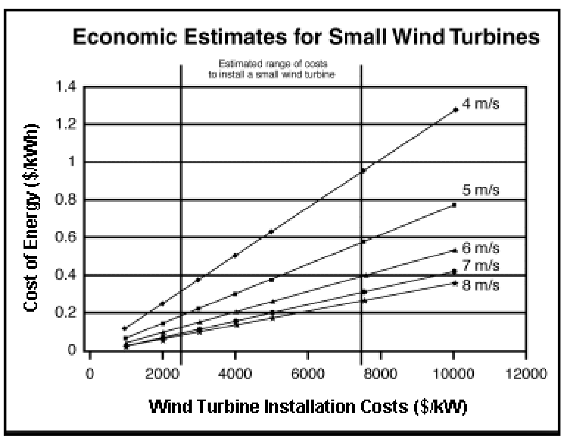


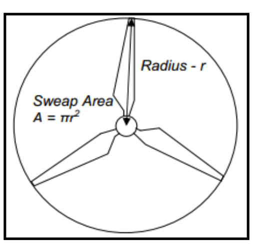
Capacity Factor (CF):

- The fraction of the year the turbine generator is operating at rated (peak) power rated (peak) power
  Capacity Factor = Average Output / Peak Output
  ≈ 30%

- CF is based on both the characteristics of the turbine and the site characteristics (typically 0.3 or above for a good site).[4]

3. APPLICATION





There can be many miniature windmills which can be attached to the roof of the trains. The windmills are to be placed after some periodic distance. The more the number of the windmills, the more energy will be stored. This energy will be used to power the lights and fans in the trains These large scale projects are the best way of going about meeting our energy needs. We should by generating power from them, we can:

1) reduce our dependency on the national grid

2)distribute the load on the system.

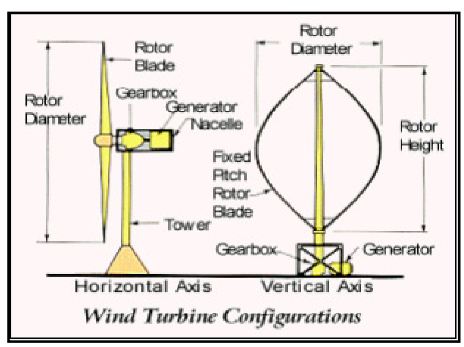
3)cut down on the energy lost in transmission.[5]

Assuming a set of values we can find out the amount of energy that can be harvested.
Blade length (l)= 1 m.
Wind Speed (v)= 60km/hr = 16.7 m/s.
Air density(ρ) = 1.23 Kg/m^2
Power coefficient(Cp) = 0.4
l = r = 1m.
A= π*r*r = 3.14*1*1 = 3.14 m^2
$P_T = 1/2 * \rho * A * v^3 * C_P$
$P_T = 1/2*1.23*3.14*16.7*16.7*16.7*0.4 = 3579.61$ Watt.

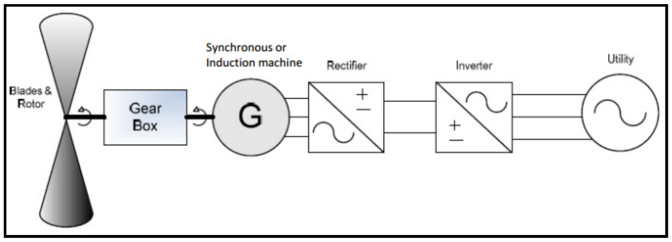
This is equal to 3.58KW.
This is the power produced by one windmill. So the amount of power that will be produced by n number of windmills will be equal to n*3.58KW.[6]

This can be better understood by the fact that a single miniature windmill of radius 1 m can run about 180 Incandescent 20W bulbs. Or a single windmill of radius 1m can charge about 40 Laptops of 90 W each.

Length of Blade	Net Power(If speed is 13.8 m/s)
0.5m	507.51 W
0.7m	994.71 W
0.9m	1644.32 W
1.1m	2456.33 W



Blades are attached to the hub. The Drive Train is the mechanism that transfers the energy from the rotor shaft to the generator. The Generator can be either synchronous or asynchronous.



Wind speed patterns can be depicted as a wind speed spectrum. A high value indicates a significant change in wind speed over the corresponding time period.

The control mechanism is an overspeed control that allows the rotors to be slowed down or stopped. Its purpose is to optimize aerodynamic efficiency, keep the generator with its speed and torque limits and rotor and tower within strength limits, enable maintenance and reduce the noise.[7]

The rotational mechanical energy can be efficiently converted to other forms of energy by utilizing a good rectifier and inverter system. The better the system, the more will be the efficiency.

4. FURTHER DEVELOPMENTS

The performance can be further improved by improving the capacity by implementing larger blades and superconducting magnets. It can be improved further by implementing site specific designs. To improve the reliability, forecasting tools can be added. The wind-speed will depend mostly on the speed of the running trains. Hence it will be more effective in high speed trains. The energy generated can be possibly stored and used for later purpose. This can be even implemented on other fast moving vehicles provided that the amount of power obtained from windmills is sufficient.[8]

5. CONCLUSIONS

The values assumed are normally defined by the turbine designers but it is important to understand the relationship between all of these factors and to use this equation to calculate the power at wind speeds other than the rated wind speed. Having knowledge of how a turbine behaves in different wind speeds is critical to understand the income lost. Over and above this system of implementation will do a lot of good to the Indian economy as the railways are always plagued by energy crisis.

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