PARAMETRIC STUDY OF TURBINE MOUNTED ON TRAIN FOR ELECTRICITY GENERATION

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Abstract – *This paper gives detailed literature knowledge about the main factor affecting the performance of turbine mounted on moving train. High wind pressure is generated by speeding train, which forces back the blade of turbine and hence the rotor rotates which generate electricity. Using a turbine mounted on train roof converts the kinetic energy of wind into the electric energy. Today, there is crying need to look into renewable source of energy because Fossil fuel are almost at their saturation level harnessing of energy from wind can be helpful or revealed many application.*

Key Words: Wind energy, Shrouded turbine, Blade profile, Angle of attack.

1. INTRODUCTION

Today many power generating techniques are employed but somewhere they affect the environment. It's indispensible that we find a new way for harnessing of energy from renewable sources. Wind is a free renewable source of energy. Wind has been harnessed as an energy source for over 100 years. The common incentive to pursue wind energy is that it's financial as well as eco friendly.

Wind is a by-product of solar energy. Approximately 2% of sun's energy reaching the earth is converted into wind energy. The surface of earth heats and cools unevenly creating atmospheric pressure zone that makes air flow from high to low pressure area. This flowing air have some kinetic energy which can be converted into electric energy with the help of turbine mounted on the roof of moving train. This energy can be use to run various electrical components either simultaneously, or charging DC battery which can be used latter.

Turbine may be Horizontal Axis Wind Turbine(HAWT) and Vertical Axis Wind Turbine(VAWT).

HAWT: this is the most common wind turbine design. The rotor of horizontal rotates around horizontal axis and rotating plane is vertical to wind. The technology of HAWT is more mature. Some are designed to operate in an upwind mode, in which blade faces the wind first. Other design operates at downwind mode in which wind passes the tower before striking the blade.

VAWT: the rotor of vertical axis wind turbine rotates around a vertical axis. the main advantage of it is that it can receive wind from any direction ,so when the wind changes, the wind turbine of this kind has no need to initiate. They don't take advantage of high wind speed at higher elevation above the ground. the basic VAWT design are the Darrius, which have curved blade and efficiency 35%, the Giromill which have straight blade, and efficiency 30% and the Savonius which uses scoop to catch the wind and efficiency 30%.

Figure 1

2. EXPLANTION

Wind turbine design is crucial in order to make wind turbine as per expectation. Innovation and new technologies goes for designing turbine haven't stopped.

2.1 Selection of turbine

Most of the research proposed the Horizontal Axis Wind Turbine over Vertical Axis Wind Turbine. Many reason are given for such which are as follows

They are low speed because only one blade of turbine work at a time.

They have an additional drag when their blades rotates.

Due to the vertically oriented blade design, the blades tend to flex and twist as the rotor assembly spins faster and faster. The centrifugal force generated by the spinning blades has been reported to cause stress and fatigue on some blade designs that occasionally results in them breaking

VAWT tend to lower output machine that derive more power from torque than rpm, which result in greater machine weight and cost.

But today opting another wind turbine that is shrouded turbine can be best for generation of electricity on moving train because they are small as well as more efficient so they corker to get fitted on train roof. Shrouded turbine is that has turbine enclose in a venturi shaped shroud or duct producing a sub atmospheric low pressure behind the turbine. The venture shroud are not subjected to Betz limit and allow the turbine operate at higher efficiency claimed improvement vary, from 1.15-4 times higher power output. The Betz limit of 59.3% conversion efficiencies for turbine in an open flow still applies, but for larger shroud cross section area rather than small turbine cross section area.

A shroud of suitable geometry can increase the flow velocity across the turbine by 3-4 times the open or free stream velocity. More power generated mean greater returns on investment.

Figure 1

2.2 Blade design

Generally, wind turbine blades are shaped to generate the maximum power from the wind at the minimum construction cost. But wind turbine blade manufacturers are always looking to develop a more efficient blade design. Constant improvements in the design of wind blades has produced new wind turbine designs which are more compact, quieter and are capable of generating more power from less wind. Its believed that by slightly curving the turbine blade, they're able to capture 5 – 10 percent more wind energy and operate more efficiently in areas that have typically lower wind speeds.

Flat blades are the oldest blade design used for thousands of years on windmills but are now becoming less common than other blade designs. The flat blades push against the wind, and the wind pushes against the blades. The resulting rotation is very slow because the blades that are rotating back on the up stroke after generating power are in opposition to the power output. This is because the blades are acting like huge paddles moving in the wrong direction

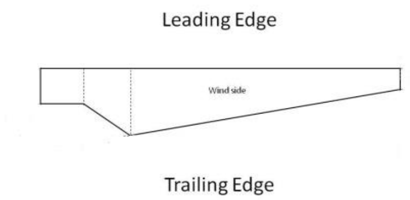

Figure 2

Curved blades are very similar to a long aeroplane wing (also known as an aerofoil) which has a curved surface on top. The curved blade has air flowing around it with the air moving over the curved top of the blade faster than it does under the flat side of the blade, which makes a lower pressure area on top, and therefore, as a result, is subjected to aerodynamic lifting forces which create movement. These lifting forces are always perpendicular to the curved blade's upper surface which causes the blade to move rotating around the central hub.

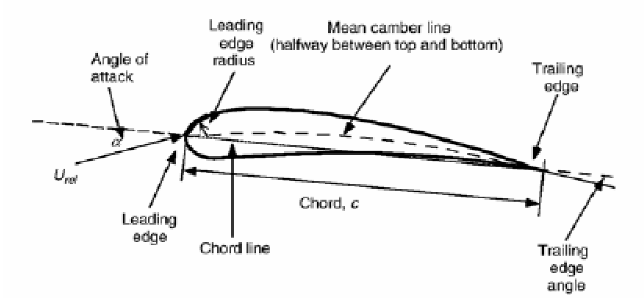

Figure 3

2.3 Number of blade

The limitation of available power in the wind means that the more blades there are, the less power can extract. The consequences of this is that each blades must be narrower to maintain aerodynamic efficiency. The total blade area as a fraction of the total swept disc area is called solidity, and aerodynamically there is an optimum solidity for a given tip speed; the higher the number of blades, the narrower each one must be. In practice optimum solidity is low which means that even with only three blades, each one must be very narrow. To slip through air easily the blades must be thin relative to their width, so the limited solidity also limits the thickness of blades.

2.4 Angle of attack

The angle between the direction of the oncoming wind and the pitch of the blade with respect to the oncoming wind is called "angle of attack". As this angle of attack becomes larger, more lift is created but as the angle become even larger , greater than 20°,the blade will begin to decrease lift. There is , unfortunately, also a retarding force on the blade: the drag. This is the force parallel to the wind flow, and also increase with angle of attack. So there is ideal pitch angle of the rotor blade to creates the best rotation

To increase wind turbine blade efficiency, rotor blades needs to have aerodynamic profile to create lift and rotate the turbine but curved aerofoil blade are difficult to manufacture but offer better performance and high rotational speed making them ideal for electrical energy generation.

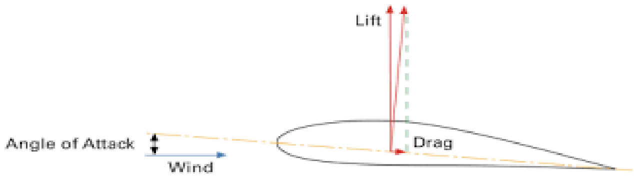

Figure 4

Tip Speed Ratio(TSR)

It's of vital importance in designing a wind turbine. It's a ratio between the tangential speed of tip of blade to the actual speed of wind. It is related to efficiency

$$\alpha = \frac{\textit{tip speed of blade}}{\textit{wind speed}}$$

If TSR(tip speed ratio) increase results in higher noise and strong blade due to large centrifugal force and if too low turbine tends to slow or stall. Turbine are designed with optimal TSR to extract as much power out of the wind as possible. Following table showing the optimal TSR's for a given number of blade are

Tip Speed Ratio	Blade
6	2
5	3
2	5

2.5 Betz limit

Indicates the maximum power that can be extracted from wind. Albert Betz a German physicist who calculated that no turbine could convert more than 59.3% of the kinetic energy of wind into mechanical energy in turning a rotor. This is known as Betz's limit, and is the theoretical maximum power coefficient for any wind turbine

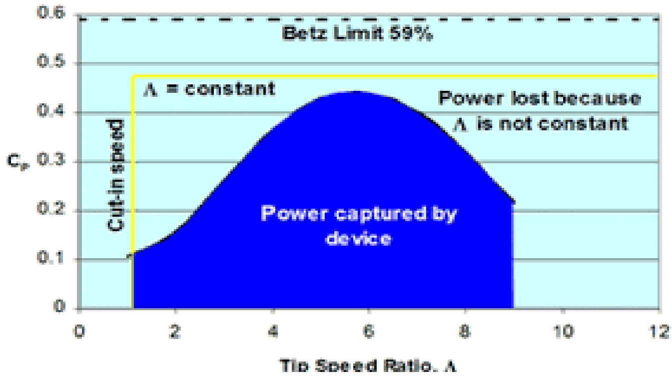

Figure 5

2.6 Power coefficient

It is the ratio of actual electrical power produced by wind turbine divided by the total wind power flowing into the turbine blades at specific wind speed. Power coefficient represent the combined efficiency of various wind power system components which includes shaft bearing and gear train

$$Cp = \frac{\textit{actual electrical power produced}}{\textit{wind power in turbine}} = \frac{P_{OUT}}{P_{IN}}$$

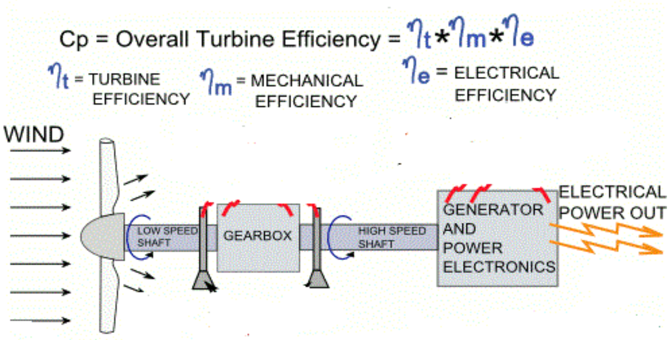

Figure 6

2.7 Mathematical formula

Wind is generated due to the movement of wind. The energy associated with this movement is kinetic energy and is given by following expression

$$\textbf{kinetic energy} = \frac{1}{2} m v^2$$

m=air mass in kg
v=velocity of air mass
hence, the expression of power can be derived from

$$\text{power} = \frac{dE}{dt}$$

$=\frac{1}{2}\frac{d}{dt}\{mv^2\}$

$=\frac{1}{2}\frac{d}{dt}\{Q\rho v^2\}$

$=\frac{1}{2}\rho\frac{dQ}{dt}v^2$

here , $\frac{dQ}{dt}$=rate of discharge=A*v

where,A=cross section area of blade movement

power=$\frac{1}{2}\rho A v^3$

hence, extractable power of wind=$P_{OUT}=\frac{1}{2}\rho A v^3$Cp

2.8 Electrical System

Blades of turbine transfer the kinetic energy of wind into mechanical energy, then generator is the unit of wind turbine that convert the mechanical energy into electrical energy. Electrical system of turbine comprises of alternator and rectifier which gives the final dc voltage which can be stored in battery which will run the electrical component inside the train.

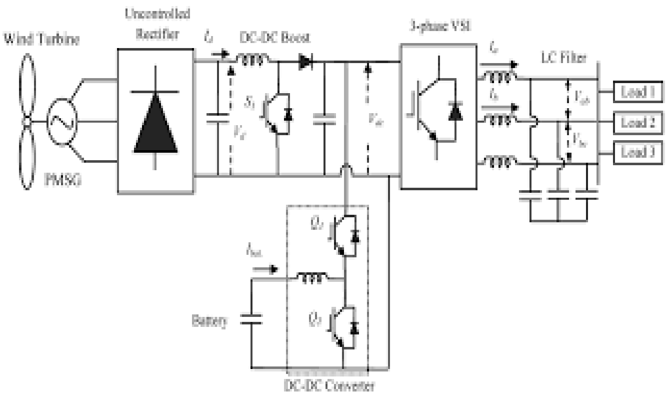

Figure 7

3. FUTURE DEVELOPMENT

Performance of wind turbine mounted on train roof can be improved by using super magnet in generator can highly improve the performance of turbine but increases the cost proportionally. As the size of turbine mounted on train is saturated after certain dimensions so increasing blade size is not a good option.

Using advance material for blade and hub section can reduced the cost. Nowadays direct drive turbine are gaining huge popularity they completely removed the gear box these type of turbine can be employed on the roof of train to cover the cost and weight. Modern design which locate the blade upwind instead of downwind have significantly reduced the level of infrasound. Scientist and government authorities have found the low level of infrasound emitted by wind turbine pose no health issue.

4. Conclusion

Studies reveal that harnessing energy from moving train can be very effective. It can meet up the power requirement. There is huge potential of generating electricity from moving train if detailed analysis on turbine could be done on different parameter like blade profile, turbine type, angle of attack, power coefficient, cut-in and cut-off speed. Shrouded turbine comes out to be the best as they extract maximum power and their compact structure make them more reliable.

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