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A Novel Technique for Power Generation in Traction System Using Renewable Source

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Abstract: *Presently increasing use of renewable sources replaces the use of fossil fuels like coal, oil and natural gas. Conventional energy sources are altered by renewable energy sources in almost all the areas, wherever it can be applicable. Wind energy is treated as one type of investment due to its several advantages such as low running cost, greater life span and so on. Due to the use of such type of renewable energy source, power generation by conventional sources can be reduced. Here a novel technique is demonstrated specifically for traction system. In traction systems, ample amount of energy is used to drive an engine and also provide ac as well as dc power to operate the lighting scheme of a train. So here power required for lighting can be generated using a roof top wind turbine which will be mounted on the train coach. In this paper a new technique is implemented for design of shaft and turbine blade so the additional energy saved due to the use of wind turbine can be utilized for areas which are less electrified. The mathematical calculation is compared with the hardware results. Here, an attempt is made to reduce the loading of grid compared to existing system.*

Keywords: *Renewable energy sources, Wind Energy, Shaft design, Wind Turbine, Traction System, Wind speed calculation, Wind turbine blade.*

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I. INTRODUCTION

It has been an undeniable fact that the railways are attaining a ceiling trend among various modes of transportation. It has been the cheapest and the most favorable mode of transport among commuters and non-commuters. The idea of making traction system as a medium that aids or spur power generation is both practically viable and advantageous for encouraging cleaner energy and simultaneously reducing the overall load consumption by the traction system. On considering India's scenario, wherein the traction system consumes 22% of the total electrical power generated per year. Out of this consumption, 12% is utilized for lighting load and various other appliances inside traction and railway coaches. In recent trends, the use of renewable energy source is increasing as an alternative to non-renewable energy source to fulfil the demand of eco-friendly power generation. In present work, wind energy is utilized as a power source and its structure is designed to mount it on roof of the railway coach. Thus, it will generate enough electric power to supply the lighting load for most of the coaches. The basic block diagram for power generation is shown in Fig. 1. It can be clearly examined from the block diagram that wind flow is directly reflected on the wind turbine blades which are coupled to the rotor shaft. Gearbox coupling is used for speed controlling purpose. Once the blades are under influence of wind flow, they will start to rotate and hence will rotate the alternator which will further generate the alternating power with fixed frequency.

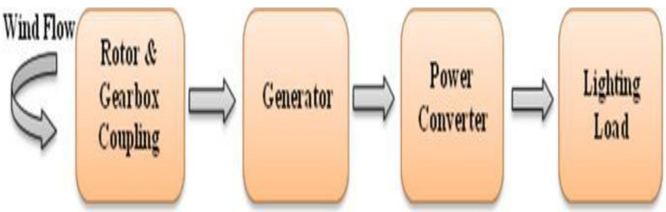

Fig. 1. Block Diagram of the system.

Various lighting loads in the traction system uses dc power. For that, an ac to dc converter called as a rectifier is used to convert the generated ac into dc and hence will feed the demand of lighting load. The main objective of this research work is to reduce this consumption or rather supply this demand by any other means of energy excluding coal or any other non-renewable source. So, the basic idea of this research work substantially focuses on the generation of ecological and dynamic electricity from the very motion of railways, i.e. designing and development of rooftop wind power generator and implementing the same on the railway coach. Every time train moves, wind flow will drive the wind turbine and hence will produce an electrical energy, enough to power the demand of lighting load of about 1.5 kW per coach. The successful operation of this project at practical level may reduce the traction power consumption by a large amount if viewed at national level. The excess electricity which is saved can be utilized to fulfill the demand of several places which experiences shortage of the same.

Various existing topology and methodologies may prove useful to consider the overall economical aspect and for the safe operation of turbine. First of all, calculations related to the shaft design are done, followed by the calculations for selecting the blade profile and all the dimensions obtained are further used for selecting the material. From that, the lift and drag force acting on the material are decided. After some extensive literature review on the types of blades vertical axis wind turbine has been proved to be the most efficient technique for the present application. The design of the blade shape is kept curved like longitudinally extended hemispheres, as will be explained in the proceeding sections.

II. COMPONENT'S TOPOLOGY

A. Design of Shaft

Shaft is very important parameter in a wind turbine. It provides necessary connection between the blade and generator. Once wind energy strikes the blade, then blade starts rotating and therefore, because of its connection with the shaft, it administer the rotational movement to the generator and thus an electrical energy is generated.

There are different types of material used in the shaft such as carbon steel, stainless steel, alloy carbon steel etc. Selecting the type of material is dependent on the constant of bending and torsion force which are acting on it, and then it utilized for the necessary application.

B. Design of Turbine Blade

Blades are the deciding factor for power generation. Depending on its application, their type, shape, and size may vary and accordingly the power output changes. And for the selection of the turbine, blade profile must be known for the force acting on the blades. Two types of forces i.e. twist and drag force are acting on the blades and according to that, the twist angle is decided. So, for the proper selection of blade profile, these all things must be known.

C. Calculations

In the process of designing all the parameters related to the wind turbine required by the load, the blade material, design of the shaft and other assembly are calculated.

For the calculation of load, assuming one coach with different lighting load, generally in the train for lighting purpose and fan are required.

Let us consider,

Power required by fan = Watts × No. Of Fan

= 20 × 28

= 560

Power required by Lights = Watts × No. Of Lights

= 24 × 36

= 864

Total Power	Power		Power
Demand	=Required	+	Required
of the coach	By fan		By lights

= 560 + 864

= 1424 Watts

= 1500 Watts (Approx)

The total power demand obtained from the above calculation can be used to obtain the value of current in a single coach. For 110 Volts or 220 Volts DC supply, the value of current obtained is 6.2 Ampere.

So finally, from the above calculations, it can be said that the power demand and current in a single coach is around 1500 Watts and 6.2 Amperes respectively. This requirement can be easily satisfied by mounting the vertical axis wind turbine on the roof of the train. Once train races through the track, the flow of wind is reflected on the turbine and it starts rotating.

Blade Calculation:

This calculation holds great importance on the profile of wind turbine. Once they start their rotation, an electrical energy is produced. Following calculations are important for designing blade profile.

Length of Blade = 6 × H. P × 1/4

= 6 × 742.5 × 1/4

= 1000 mm

Using this equation, we can select the length of one blade. Here, 6 blades are used because on increasing the number of blades, the force acting on the blades is less. As the total force acting is divided among the total number of blades. Thus the force on an individual blade will be reduced. All the blades are 60˚ apart from each other.[3]

Here, identical forces are acting on the blades in a resultant manner. One will be for the velocity of the train and other will be for the movement of the train. Hence, it can be said that 6 blades are used for getting 1.5 kW per coach and appropriate blade material is selected to withstand the force acting from all the directions.[4],[5]

Main Calculation:

The following Data is assumed for the main calculations

Force (P1) = 200 N

Angle of Twist (θ) = 180°

Coefficient of Friction (μ) = 0.2

Modulus of Rigidity (G) = 79300 N/mm2 Length of the Shaft (L): 1000 mm

Bending Moment (Mb) = (W × L) / 4

= (200 × 1000) / 4

= 50000 N.mm

Torsional Moment (Mt) = $(60 \times 10^6 \times P) / 2\pi n$

= $(60 \times 10^6 \times 1.5) / 2\pi \times 45$

= 318471.33 N.mm

= 318.47133 N.m

(P1 / P2) = $e^{\mu\theta}$

= $e^{0.2*\pi}$

(P1 / P2) = 1.8744

Here, P1 = 200 N, so P2 = 200/1.8744 → P2 = 106.697 Equivalent Bending Moment = $[kbMb + \{(kbMb)^2+(ktMt)^2\}^{1/2}]$

= $[1.5\times50000 + \{(1.5\times50000)^2 + (1\times318.471)^2\}^{1/2}]$

= 150000 N.mm

Equivalent Torsional Moment = $\{(kbMb)^2+(ktMt)^2\}^{1/2}$

= $\{(1.5\times50000)^2 + (1\times318.471)^2\}^{1/2}$

= 75000 N.mm

Bending Stress (σb) = $(32\ Mb) / \pi\times d^3$

$290 = (32\times150000) / \pi\times d^3$

$d^3 = (32\times150000) / \pi\times290$

d = 17.40 mm or d = 18 mm

So, the required diameter of shaft for the present model is 18mm.

D. Selection of Bearings & Gears

Bevel gears prove to be an effective solution for transmitting vertical motion into horizontal motion. Hence, bevel gears are selected of PVC material with a gear ratio of 1:3.
Ball bearings are used where support and smooth motion is to be provided to the shafts.

E. Frame

After defining all the terms related to the turbine, it is further implemented in software to check whether the system is suitable or not. All the implementation is carried out in the software named SOLID WORKS. First design the shaft as per the calculated value. According to the calculations, the diameter of the shaft is 18 with the 1000mm length. This is suitable to withstand the power demand of 1500 watt per one coach. The shaft is made of carbon steel with alloy, to withstand the bending and torsional force acting on the shaft. The view of the shaft is shown in the Fig.2 along with all the dimensions. Left figure indicates the side view while the right figure indicates the isometric view of the shaft.

Fig. 2 Side view and isometric view of the shaft

After designing the shaft, the next step will be to design the blade which is one of the most importantcomponents of the turbine. Basically, there are two types of blades. i.e. curvature and rectangular. Curvature blade is used instead of Rectangular blade, due to the reason that once the force of the wind is increased, blades can get bend and may not be able to give the desired output. Curvature blades can withstand it easily. Here, 6 blades are used to provide the mechanical balance in all the directions and all the blades are placed 60˚ apart from one another as shown in Fig. 3.

Fig. 3. Isometric view of the blades on the connector ring

Balance connector ring and a round disc are designed and provided which can connect the blades and shaft at a common point and can offer the necessary mechanical balance in all the directions. The dimension of the ring is dependent on the outer periphery of the blade and the total diameter of a blade.

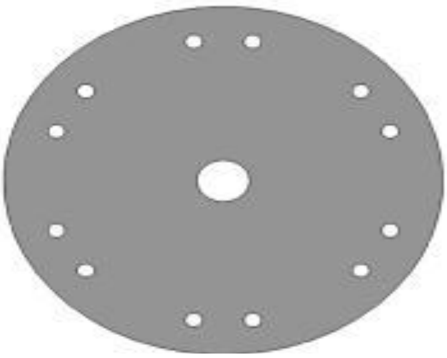

Fig. 4. Top view of the connector ring

Fig. 5. Isometric view of the blade

After designing all these parameters, its assembly is required followed by the analysis purpose. For that, the proper dimensions of all the parameters are used along with various views. After that, selection of proper material is of equal importance which is economical and can give a good performance.

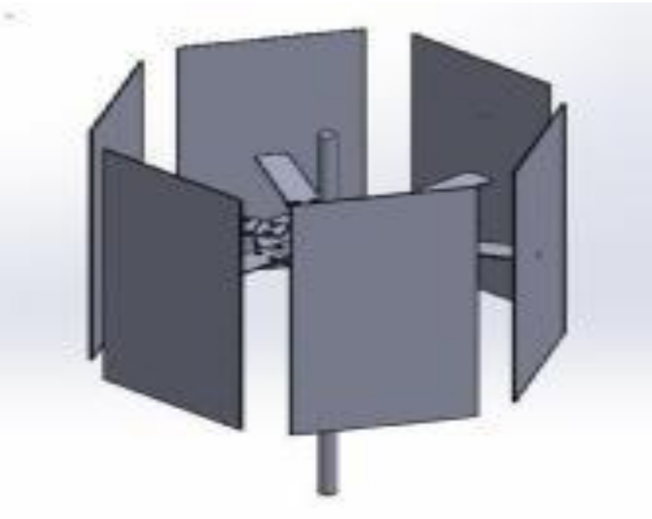

Fig. 6. Isometric views of the

Finally, the view of vertical axis wind turbine is as shown in Fig. 6. The dimension model drawing is according to Fig. 7. And the top view of the turbine is as per Fig. 8.

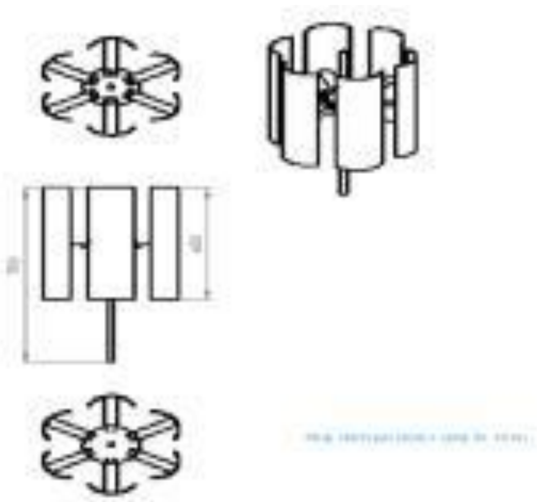

Fig. 7. Draft file of the turbine

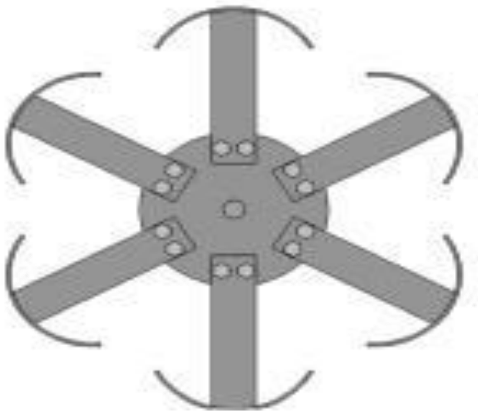

Fig. 8. Top view of the turbine

III. HARDWARE IMPLEMENTATION

Fig. 8 shows the implementation of actual hardware setup carried out in the Laboratory of SVIT, Vasad. The entire prototype was arranged sharing equivalency with the actual system.

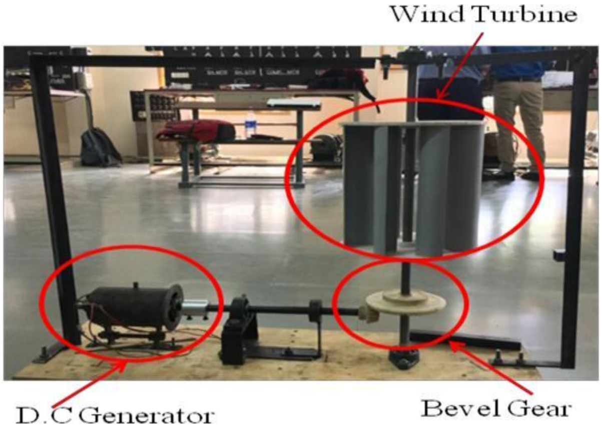

Fig. 9. Actual demo of the turbine

Commencing with the utilization of a vertical axis wind turbine, it is specifically used to capture the atmospheric wind energy and convert its kinetic energy into the rotational energy. It is further coupled to the shaft of the generator through a gear mechanism. The gear mechanism is used to control the speed of the turbine and maintain the speed as per the necessary reference speed.

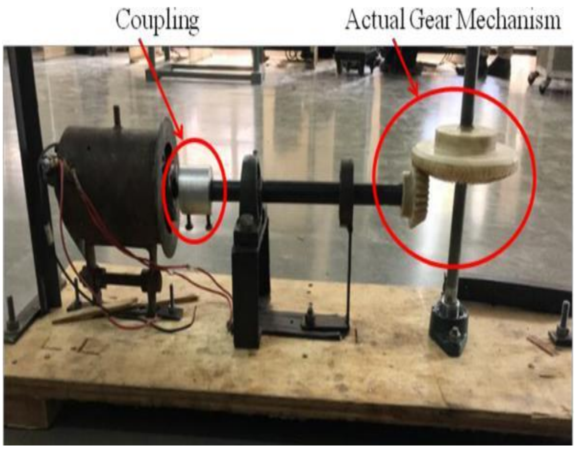

Fig. 10. Actual coupling between dynamometer and bevel gears and

Fig. 9 represents the actual coupling mechanism of the practical system. Here, bevel gear is used provided the gear ratio to be 1:3. The combination of vertical and horizontal attachment is used to offer the necessary and efficient gear mechanism as required by the system.

Further, the turbine will act as a prime mover coupled to the generator. Generator will then convert the rotational energy of the turbine into the electrical energy, which is then provided to supply the power demand of the coach.

Parameter	**Value**
Supply	220 V or 110 V
Power required per coach	1500 W
Wind Velocity	Maximum – 14 km/hr
	Minimum – 2 km/hr
Shaft Diameter	18 mm
Blade Length	1000 mm
Gear Ratio	1 : 3

IV. RESULT

Hardware implementation was proved efficient and the required results were obtained from the setup. Thus, it was evident that the idea was feasible to put forward into the practical applications. Fig. 10 shows the necessary arrangement to measure the amount of power generated. The generated power is measure using multimeter.

Fig. 10 Practical generation of voltage evident on the multimeter

Fig. 11 shows the generated voltage on the hardware implementation of the present system. Here, the implementation is done using a basic prototype which presents the equivalency with the actual traction system. Blower is used to provide the necessary wind velocity and it will rotate the turbine at 1200 rpm. It will generate the voltage of about 4 Volts. This is no doubt lower due to the constraints offered by friction in gears and bearings.

Fig. 11. Generated voltage using prototype model

Electrical demand of each coach is about 1.5 kW. To generate this huge amount of electricity, the minimum required wind speed will be around 15 km/hr. But when the wind speed is increased to around 30 – 35 km/hr, it can also generate the power of 3 kW. Hence it can electrify two coaches of the entire traction system. This will save ample amount of energy which can be further used to fulfill various different applications.

V. COMPARISON

Table 1 shows the comparison based on the method implemented for power generation for a lightning scheme in traction system. The comparison demonstrated that if energy is generated by conventional sources then no additional power saving can be done and 100% energy is used in the generation of power for a lightning scheme of a train. Rather than the conventional system, for implementing the present novel technique, only 88% energy is used instead of 100%. This preserved energy can be utilized to provide electricity to the areas which suffer from the deficiency of same.

	Method used	**Usage (%)**	**Saving (%)**
	Using conventional sources	100	0
	Using renewable sources	88	12

VI. CONCLUSION

In this paper, we have developed a novel technique which does not provide only economical benefits but also reduces adverse effects on the environment due to the increased use of conventional or non-renewable sources. Mathematical calculations are shown related to blade design and shaft design. According to calculation hardware set up is done which is a prototype model. From the obtained result, it is anticipated that our actual system will give output properly. As already described the total energy used by traction system in a lightning scheme is 12% so this saved energy can be used to scanty areas. This is further used to improve social as well as an economical condition of our country.

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