CFD ANALYSIS ON WIND FLOW CHARACTERISTICS WHILE A TRAIN PASSING THROUGH THE TUNNEL

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Abstract- Increasing demand for energy in various industrial and domestic applications has imposed great challenge on generating the energy and sources of energy. One end is worried of increased demand for energy while other end is worried on most dependable fossil energy sources are getting exhausted. Fossil fuels have another issue related to environment and human health. In order to sustain the energy supply system two areas has to be given more importance under research and development, one to increase the efficiency of existing applications thereby to reduce the energy utilization, the second is to develop more renewable energy sources. One of the popular renewable energy source is the wind energy which is abundantly available in the earth atmosphere. Problem with wind energy is its consistency and efficiency of converting it into useful electrical energy. Most researchers are working on improving the efficiency of wind energy harness systems.

Keywords- Renewable Energy, Wind Energy, CFD, Wind Turbine

I. INTRODUCTION

Energy is a serious issue around the globe, millions of applications requires billion joules of energy in everyday operation. Most of the energy source for these applications are mainly of non-renewable sources of energy such as petrol and coal which give out harmful effects towards the environment and human life. In order to find alternative energy sources, multiple research and development have been carried out to overcome the energy consumption problem. There are few alternative energy sources such as solar energy, wind energy, hydropower energy and biomass energy. Future prospective of energy sources indicates that renewable energy sources growth is the highest compared to the growth of other energy sources [1]. According to World Energy Resources [2] energy defisiency by the lack of fossil fuel is majorly recoverd by renewable energy sources.

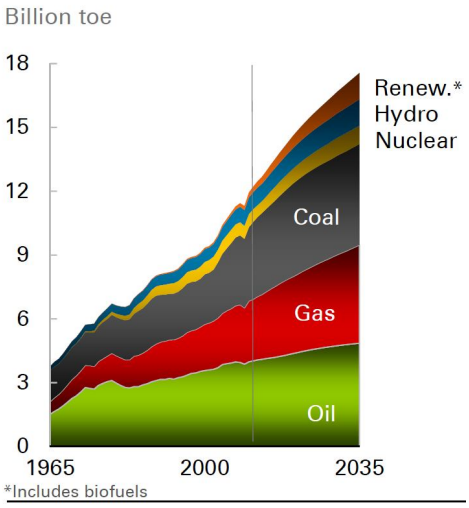


Fig 1. Fuel consumption scenario forcast 2035 [1]

Wind energy is one among the renewable energy that is abundant and available free in the atmosphere. Global Wind Energy Council (GWEC) in collaboration with Greeenpeace International has conducted study on current and forcaseted global cumulative wind power capacity [3].

Demand for wind energy harnessing is clearly shwon in their study. Other than various windmill projects, some projects were involved moving vehicles on road causing accelerated wind movement that can be captured as wind energy to generate electricity[4][5][6].

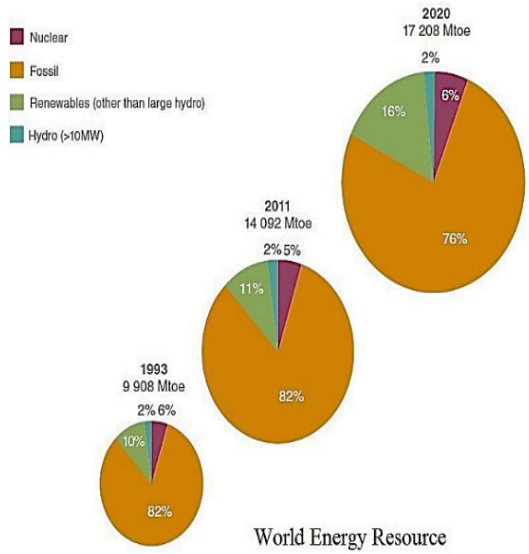
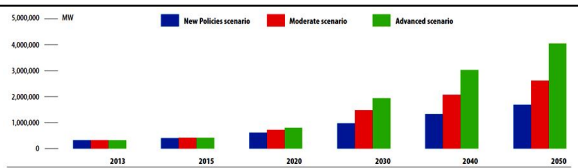


Fig 2. World energy resource trend for 2020[2]

Arizona States University project'highway installed horizontal wind turbines' indicated production of 9600 kWh of energy per yearfor an average vehicle speed of 70 mph passing by the highways.

Many such projects includes highway vertical –blade wind turbine, city speed turbine and many more [4][5][6][7].



	2013	2015	2020	2030	2040	2050
New Policies scenario						
MW	318,128	396,311	610,979	964,465	1,324,814	1,684,074
TWh/a	620	972	1,499	2,535	3,482	4,426
Moderate scenario						
MW	318,128	413,039	712,081	1,479,767	2,089,261	2,672,231
TWh/a	620	1,013	1,747	3,889	5,491	7,023
Advanced scenario						
MW	318,128	420,363	800,615	1,933,989	3,024,473	4,042,475
TWh/a	620	1,031	1,964	5,083	7,948	10,624

Fig3. Global Cumulative Wind Power Capacity forcast 2050 [3]

II. OBJECTIVE AND METHODOLOGY

Present work is interested in harnessing wind energy where computational design analysis wereconducted on extraction of wind energy while a train is passing through a tunnel. Main objective of the work is to find viable for practical application of wind turbines in a train tunnel to extract wind energy in an efficient manner.

Train dimensions were taken from KTMB Malaysia manufacturedby CSR ZhuZhou Electronic Locomotive Co. Ltd. The train carmeasures 3.905min height, 2.75m in width and 22.8m in length with speed of 70km/hr (19.4m/s) [8].



Fig 4: KTMB Malaysia Train Class 92 EMU [8]

Studies have shown that as the speed at wind trubine hub increase the generation cost reduces substantially which is illustrated in Fig 5 [2]. Some existinghigh speed trains are potential with speedranging from 315 kphto 450 kph [9][10]. Thus harnessing the wind energy from passing train could be more realistic in future. Ohya Y. et.al conducted study on various types of shrouded wind rurbine with wind lens [11].A shrouded wind turbine with wind lens with ~1.5 m outer diameter is assumed to be applied for wind harnessing.

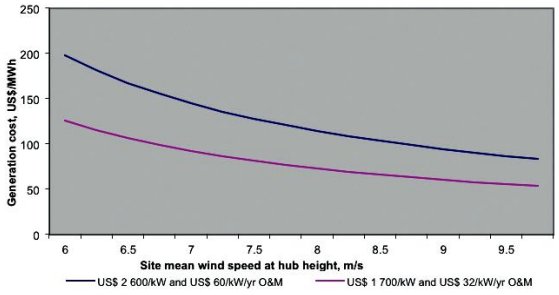


Fig 5. Typical generation costs versus wind speed [2].

Out of two major factors considered during this studyfirst one is the cross sectional shape of the tunnel and the second is the ideal position of the wind turbine from the tunnel exit.

A. CROSS SECTION OF WIND TUNNEL

Shape of the tunnel cross section varies based on the architecture and region. In the initial study effect of cross section on the wind velocity and pressure through the tunnel were considered. Two of the most common cross sectional designs used in this study are shown in the Fig 6. Most of the dimensions were maintained common for both the designs like height (4.9 m) and width (2.75 m) of the train, track width (5.75 m) and train over head height (~2 m).

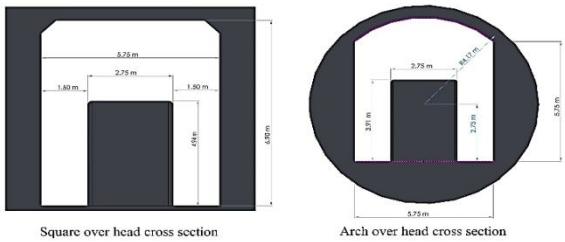


Fig 7. Tunnel over head cross section (a) Square (b) Arch

B. POSITION OF WIND TURBINE

Accelerated wind flowing through the tunnel while the train passing will have the air speed with various ranges through out the tunnel. Wind speed basically depends on the train speed as well as the position of the train nose from the tunnel exit, the factor is shown in Fig 8 as 'x'. Highest speed can be noticed at any position above the train at a distance 'y' from the tunnel entrance.

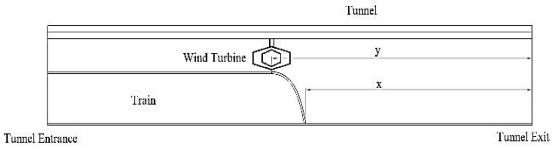


Fig 8. Strategic positioning of wind turbine in the tunnel

Various simulations created with tunnel shape and position of train nose from the tunnel exit are tabulated in the Table 1. Aproximated maximum velocity in the tunnel were extracted after the simulation.

Table1: Simulation setup

Tunnel overhead cross section	Position of train nose from the tunnel exit (x) m	Max Wind Velocity m/s (approximated)
Square 1	60	28
Square 2	40	28
Square 3	20	28
Square 4	~0	35
Arch 1	60	27.5
Arch 2	40	28
Arch 3	20	27.5
Arch 4	~0	34

III. CFD SIMULATION

In the present work, computational fluid dynamics (CFD) simulations were conducted to analyze the various position of train in the tunnel. ANSYS 14 FLUENT was used as the CFD tool. Mesh was generated using ANSYS meshing tool.Velocity of the train was 19.4 m/s constant for all the simulations.

Some of the assumptions made during the simulation are stated bellow.

a. Density of the air was constant for all the simulations

b. Size and shape of the train was constant for all the simulationss

c. Front car of the train alone was considered for the simulation, aerodynamic effect due to second cars on air velocity was neglected.

IV. RESULTS AND DISCUSSION

A computational simulation were conducted to study the wind flow characteristics in a tunnel while a train passing though it. The objective of the study was to identify the ideal location for wind turbine to be placed to harness the widn energy. Out of two tunnel overhead shapes under the study, both have most similar wind characteristics for various positions of the train car.

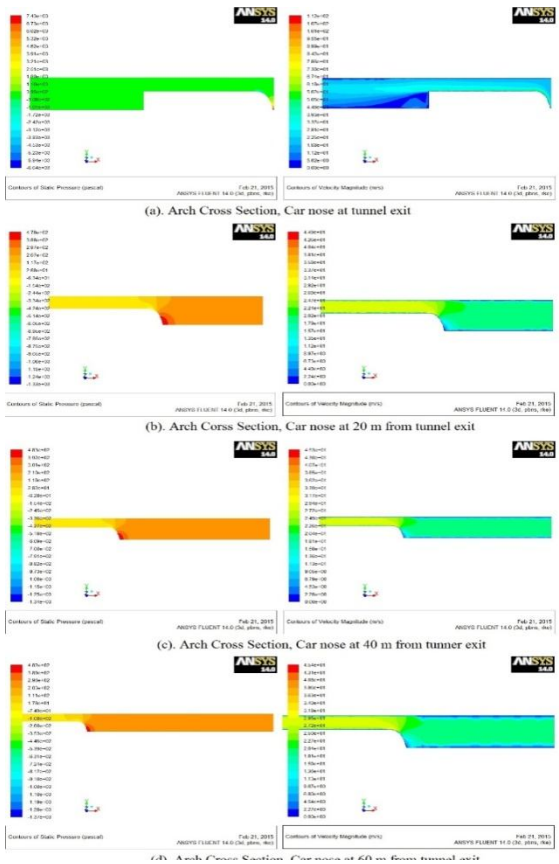


Fig 9. Pressure and Velocity patern for various positions of the car under Arch overhead cross section of the tunnel

While studying the position of the car on the wind speed, it is observed that the wind speed was recorded high when the car nose reaches to the tunnel exit. This was due to abondent quantity of air in the outer atmosphere rushing into tunnel as the car shears the wind. Where aswind speed was approximately 28 m/s for the car position of 20 m, 40 m and 60 m away from the tunnel exit. This effect is due to limited availablility of airwithin the tunnel got sheared while train car passing through the tunnel. It is also noticed that the veolity was distributed evenly except at the boundaries due to slip.

Wind turbine can be positioned aproximately one car length away from the tunnel exitwhere maximum wind velocity with steady flow is observed. Placing the turbine very near to the tunnel exit or near to the tunne inlet would either cause lack of wind speed or unsteady wind flow.

V. CONCLUSION

Renewable energy sources are getting more attention in current energy trends due to sustainalbe issues. Wind energy is one of the potential renewale energy abondantly available and easily extractalbe. Many reserchers are working on various ways to extract wind energy and also to optimize the extraction efficiency.

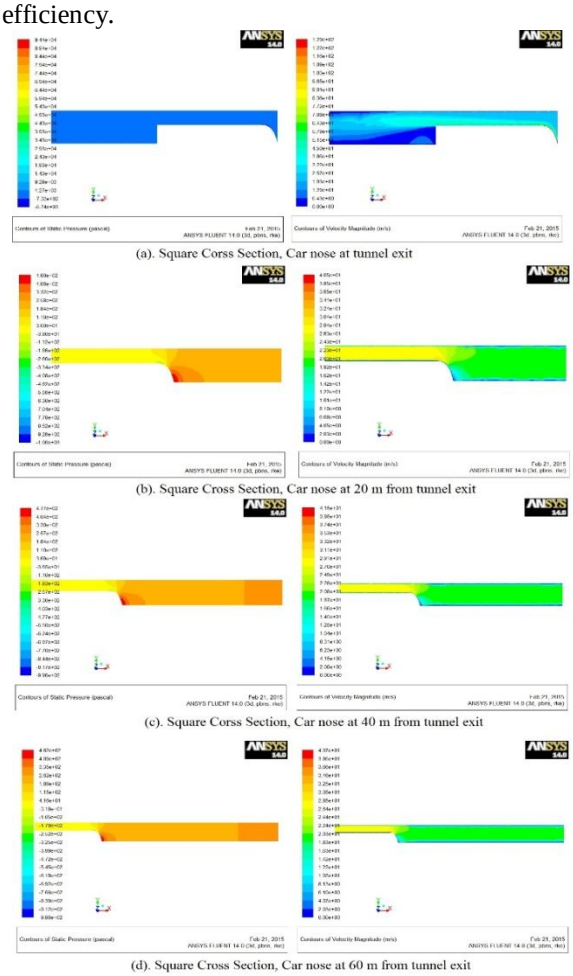


Fig 10. Pressure and Velocity patern for various positions of the car under Square overhead cross section of the tunnel

Extracting wine energy while vehicle passing is getting more interest among the researchers. Many highway and city road projects were under implemetation. In the current work extraction of wind energy while train passing through a tunnel was considered for the study. Flow characteristics of wind and ideal positioning the wind turbine were the main objectives considered. A numerical simulations were conducted to analyze the wind characteristics. Computational fluid dynamics by Ansys Fluent was used as the tool for the study. It was noticed that the wind velocity was increased by 1.5 times of the train speed whiel it passing through the tunnel. Maximum velocity was observed at the tunnel exit rather than the various positions of the train car within the tunnel. Since the wind speed was maximum when train was at the tunnel exit, it was idela to position the wind turbine approximately one car leangth away from the wind tunnel exit. For given overhead height eithe the square or the arch cross section will end up with same amount of wind speed and wind flow charecteristics through out the tunnel. A very minimum differences were observed due to the shape effect.

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