

A Proposed Combined Renewable Energy System for Train

Mohammad Azazur Rahman¹, Mohammad Woli Ullah², Muhammad Mostafa Amir Foisal³, Md Saif Hannan⁴, Abdullah Al Azha⁵, Muhammad Solaiman Mohim⁶, Ahmed Afif Monrat⁷

Dept. of Electronic and Telecommunication Engineering^{1 2 3 4 5 6}, Dept. of Computer science, Electrical and Space engineering⁷

International Islamic University Chittagong^{1 2 3 4 5 6}, Lulea University of Technology⁷

Chittagong, Bangladesh^{1 2 3 4 5 6}, Sweden⁷

ezaz.ctgbd3@gmail.com¹, woli1@yahoo.com², oranta68@yahoo.com³, saifhannan@yahoo.com⁴
sakibdm2@gmail.com⁵, mohiuddinmohin86@gmail.com⁶, ahmmon-7@student.ltu.se⁷

Abstract: Renewable energy is most preferable method in the world to produce electrical power because of its low cost and eco-friendly characteristics. Wind and solar are the most significant source of renewable energy. By using those renewable energy in train, fuel consumption and carbon dioxide emission will be reduced. The amount of power which will be produced from those two types of renewable energies in train is shown by theoretical analysis. In this paper, rate of producing energy, economic benefits are shown.

Keywords: wind power, solar power, Train, Carbon dioxide, air drag, fuel.

1. INTRODUCTION

As days pass, due to the massive growth in world population and the demand for energy growing relentlessly. To keep up with the increasing demand for energy the fossil fuels are being used vastly which are pretty costly, limited and most importantly harmful for the environment. Global warming, a major threat, leading the world to be doomed according to the governments as well as the researchers is being caused by the burning of these fossil fuels. One of the eye catching fact about the fossil fuels is they are being exhausted at a faster rate which is threatening about their availability. So, the conservation of these energy sources and producing energy from eco-friendly sources are considered as a much needed step all over the world.

People all over the globe are also considering these facts seriously. That's why bio fueled, electricity driven and hybrid vehicles can be seen in a greater number now than the past few years. In addition, these options give the consumers a chance to decrease their dependency over the fossil fuels. By producing renewable energy like wind and solar from the train, dependency on fossil fuels in train can be reduced and carbon dioxide emission can be mitigated.

Wind and solar energy are the two most recognized renewable energy. Velocity of a train can be used for producing energy by using wind turbine, but its main drawbacks is air drags. [1] But in a high speed train the net energy from wind turbines is mostly satisfying. On the other end, solar panel can give an amount of energy by setting it on the roof of the train. But the output from the solar panel depends on solar radiation period and weather. [2] If the wind and solar energy producing system can be combined together in a train, the output is most significant. It will be possible to get more energy if mechanical strength of wind blade can be increased so that the blade can survive in high velocity of the train and also increase efficiency of solar panel.

The rest of the paper is categorized as follows. In section II basic theory of Wind and solar power and their formula. Proposed model is shown in section III and the power of wind and solar of the train is calculated in section IV. In Section V, discussion about the economic benefits and amount of CO₂ mitigation are presented.

2. THEORY

Wind Power: One of the most eco-friendly method of conversion of energy is to convert the air into energy. But most of the energy of air remain uncaptured by the turbine. Conversion of the energy follows the Betz law. The Betz law provides power co-efficient, which is called the Betz limit. It shows that how much energy a turbine can absorb from air. Theoretically the maximum value of Betz limit is 0.593. And practically the value range is 0.35 to 0.45. The available wind power of a turbine is equated by,

$$P_A = 1/2 \rho A V^3 C_p \quad (1)$$

Where, ρ is the air density, A is sweeping the area of air by wind turbine, V is the velocity of the air, C_p is power coefficient.[1]

$$\rho = \frac{P}{RT} \quad (2)$$

Here, p refers to air pressure in kPa, T is the value of temperature in Kelvin, R means gas constant and its value is 0.287. The value of air density is varied with places and session. Air density range is 1.14-1.22kg/m³ [8] in the perspective of Bangladesh.[8]. Here the density is assumed to be 1.2kg/m³.

Air Drag is the most formatting obstacle for wind turbine energy. When the train is moving, air drag opposes it to go forward. But the value of air drag energy is a little bit than wind energy which convert into electrical energy. The formula of air drag force is given by,

$$F_D = 1/2 \rho A V^2 C_D \quad (3)$$

In this equation C_D refers to drag co-efficient, which depends on shape of structure. The turbine in air design as half streamline blade. So C_D efficient of the turbine is 0.09 [6].

Power from the drag is,

$$P_D = F_D V \quad (4)$$

Net power from wind turbine is,

$$P_W = P_A - P_D \quad (5)$$

Solar Power: Solar energy is the source of all energy which is received from the diffusion of sunlight. It is the most renewable and eco-friendly energy source fall from the sun. It is well known by the people that solar radiation produces electricity by using solar panels. That's why in the developed country, appreciated the solar energy as the source of electrical power. If solar panels are placed on the roof of the train then it will produce electrical energy.

The solar power is calculated mathmatically as [2]

$$P_S = I_n(t) * A_S * \text{Eff}(pv) \quad (6)$$

Here $I_n(t)$ refers to isolation at time t (kw/ m²) of solar, A_S is area of single solar panel (m²) and $\text{Eff}(pv)$ means overall efficiency of the solar panels. Overall efficiency is given by,

$$\text{Eff}(pv) = H * PR \quad (7)$$

Here, H is Annual average solar radiation on tilted panels and PR is Performance ratio, coefficient for losses [2].

Total power from wind turbine and solar panel of train is shown below:

$$P_T = P_W + P_S \quad (8)$$

3. PROPOSED TRAIN'S MODEL

Now a days, the train are designed to be as aerodynamic as possible to overcome air drag force. The wind turbines on the roof of train with face air drags also, so that it is necessary to design the turbines aerodynamically. On the other end, strong mechanical strength of turbines should be ensured to protect from unwanted weather. The area of a wagon is 36m² [7]. A single turbine is set on the roof of each wagon and solar panels are placed on 34m² area.

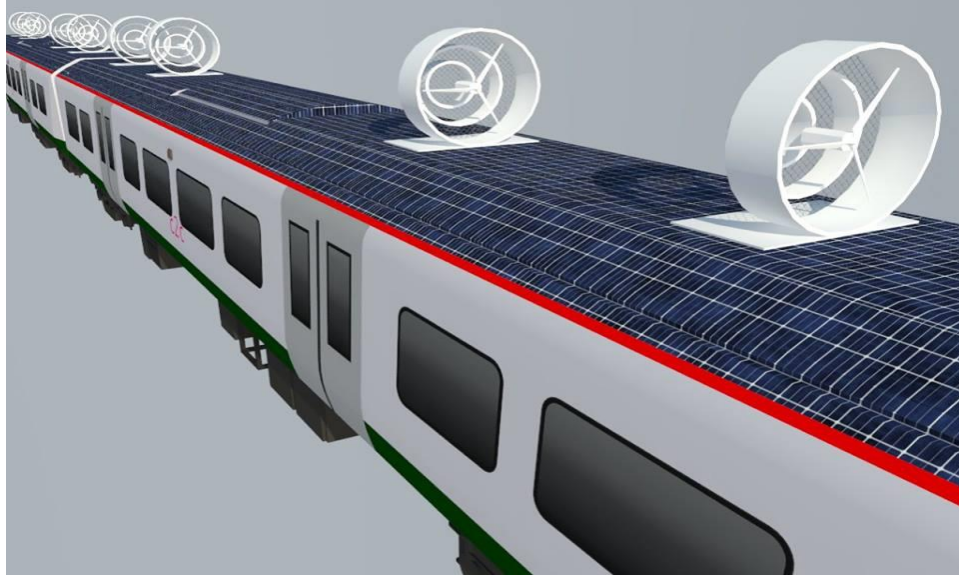


Figure 1. It has been shown that wind turbine is covered with circular fence which protects it. Roof of train is covered up with solar panel.

Basically, there has two types of wind turbine and those are VAWT and HAWT. HAWT has some more benefits over VAWT. HAWT can provide high wind speed, less aerodynamic losses so that it is highly efficient. Cost to power ratio also lower. The wind turbine comprises of blade, gearbox, break and generator. But it should be careful that mechanical strength of blades is must be strong. Otherwise it has a possibility to yet damage.

Battery will not be used because of most of the stopping time, train cannot produce energy from both solar and wind. Although, solar don't depend on train's velocity but at steady moment, train stay at station or doc yard which has shed. So solar panel can't get any power from sun generally. That's why battery is not much needed for this project. Further if battery will be used then its installtaion and maintanance cost will also be added.

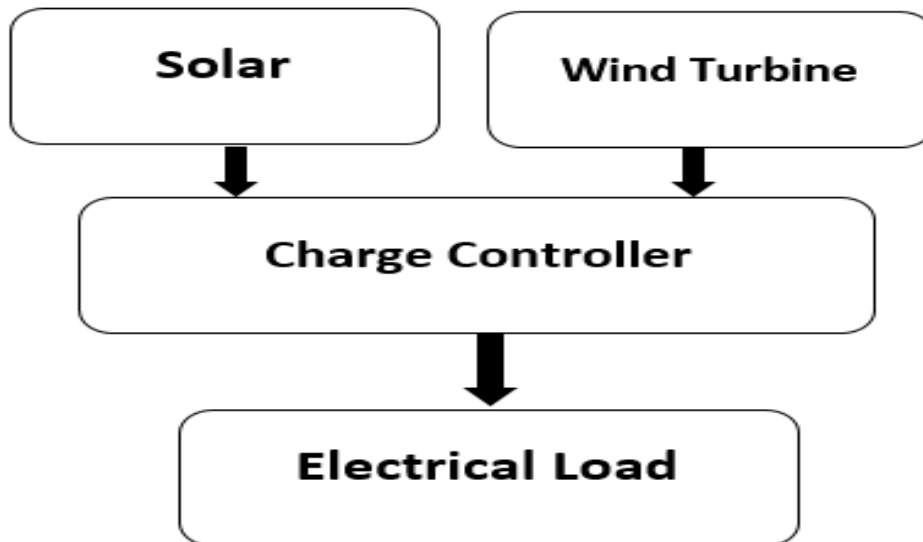


Figure 2. It has been shown the flow chart of power consumption both solar panel and wind turbine. Power from both sources comes to charge controller and then charge controller distribute it to the load.

4. POWER CALCULATION

At first, the power generation from wind turbine in different velocity of train has be calculated. To calculate the wind turbine power, we assume the length of blade is 0.5m and shape is half streamline. So the area of the turbine is 0.785m².

At low velocity (40Km/h):

$$P_A=0.5 \times 1.2 \times 0.785 \times (11.11)^3 \times 0.4 = 258.35W = 0.258kW$$

$$F_D = 0.5 \times 1.2 \times 0.785 \times (11.11)^2 \times 0.09 = 5.23N$$

$$P_D = 5.23 \times 11.11 = 58.13W = 0.058KW$$

$$P_W = 0.2KW$$

At medium velocity (70Km/h):

$$P_A = 0.5 \times 1.2 \times 0.785 \times (19.44)^3 \times 0.4 = 1384W = 1.38KW$$

$$F_D = 0.5 \times 1.2 \times 0.785 \times (19.44)^2 \times 0.09 = 16.01N$$

$$P_D = 16.01 \times 19.44 = 311.42W = 0.311KW$$

$$P_W = 1.069KW$$

At High velocity (100km/h):

$$P_A = 0.5 \times 1.2 \times 0.785 \times (27.77)^3 \times 0.4 = 4034.67W = 4.03W$$

$$F_D = 0.5 \times 1.2 \times 0.785 \times (27.77)^2 \times 0.09 = 32.69N$$

$$P_D = 32.69 \times 27.77 = 907.80W = 0.907KW$$

$$P_W = 3.123KW$$

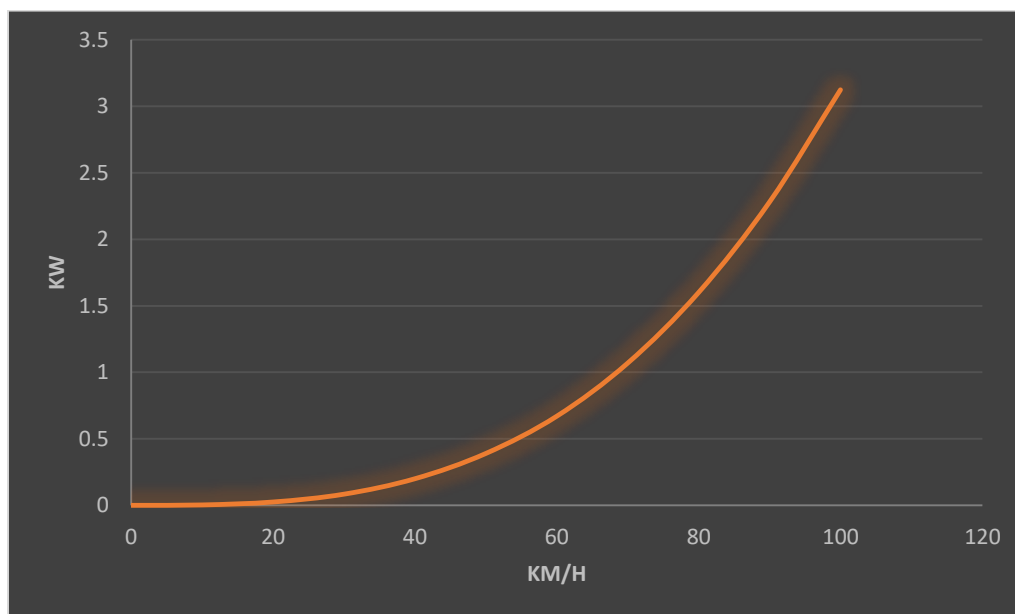


Figure 3 is the graph of power generation from wind turbine in different velocity. Power increases exponentially with respect to velocity.

Analysis of the power generation for Suborna Express train of Bangladesh: Route is Chittagong to Dhaka and travelling period is 7.00am-12.00pm [11]. Travelling time is 5 hours or 18000s. Distance between Chittagong to Dhaka is 268km. So average velocity= (268/5)=53.6km/h.

Table 1. It has been shown the analytical result of solar power got from Suborna Express in tabular format.

Available Power P_A (KW/h)	Drag Power P_D (KW/h)	Net Power P_W (KW/h/wagon)	P_w for 15 wagons (KW/h)	P_w for total travelling time(KW)
0.62	0.14	0.48	7.20	36

Table 2. It has been shown the solar power which is gotten from Suborna Express in tabular format and on this table longitude and latitude are taken for Chittagong region because most of train path are covered by this region .Taking average daylight hours ins(t) value (isolation value) with respect to the respective month and efficiency has been taken as average value which is 20% [10]. Then calculated power for solar panels in KWh/day/wagon by the equation-6 .

Longitude and latitude [5]	Month	Average Daylight (hours) [5]	Ins(t) Kwh/ m ² / day [5]	Efficiency [10]	Area Of the panel (m ²)/ wagon	Power (Ps) KWh/ Day/ wagon	Power (Ps) kwh/ Wagon	Power(Ps) (kwh) of 15 wagons /h	Power(P_s) (kwh) of 15 wagon in 5.6 Hours
23.777 and 90.399	Jan	10.8	4.72	20%	34	32.09	2.97	44.57	252.26
	Feb	11.4	5.24			35.63	3.12	46.88	265.34
	Mar	12.0	6.05			41.14	3.42	51.30	287.28
	Apr	12.7	6.48			44.06	3.46	52.04	291.42
	May	13.2	6.49			44.13	3.34	50.15	280.84
	Jun	13.5	6.98			47.46	3.51	52.73	295.28
	Jul	13.4	7.08			48.14	3.59	53.88	301.72
	Aug	12.9	6.78			46.10	3.57	53.60	300.16
	Sep	12.3	6.07			41.27	3.35	50.32	281.79
	Oct	11.6	5.33			36.24	3.12	46.86	262.41
	Nov	11.0	4.68			31.82	2.89	43.39	242.98
	Dec	10.7	4.46			30.32	2.83	42.50	238.00
Average		12.12	5.86			39.84	3.28	49.31	274.95

Total obtaining power from wind turbine and solar panels of 15 wagons in 5.66 hours (Table 1 & 2)

$$\begin{aligned}
 P_T &= P_W + P_{S(Avg)} \\
 &= 36 + 274.95 \\
 &= 310.95 \text{KW}
 \end{aligned}$$

5. ECONOMIC BENEFITS AND IMPACT ON ENVIRONMENT

The proposal design has some economic and environmental profit from the proposed design. It will reduce the fuel consumption and CO₂ emission. Fossil fuels has a bad effect on environment for some reasons. When fossil fuels are burn, some gases are released like carbon dioxide, nitrogen, and sulfur dioxide. This gases causes climate change, Green House effect and air pollution. So many researchers are doing research to find ways of mitigating the use of fuel energy.

Table 3. It has been shown the economic benefit of the system. Per liter diesel can give 10KW power and price of per liter diesel is 1.07 \$.

Obtaining Power (KW)	Diesel Consumption(L) (10KW/L) [12]	Profit/per trip(Diesel consumption*1.07 \$[15])	Annual Profit \$
310.95	31.09	33.27	10414

Further, 3.78541 liter is equal to 1 gallon diesel [13]. And 10.15kg CO₂ are emitted from 1 gallon diesel [14].

Table 4. It has been shown the amount of carbon di oxide is mitigates by minimizing the use of diesel in train.

Saving amount of diesel[gl]	Carbon di oxide reduce (10.15*amount of diesel) (KG)	Decreasing amount of CO₂ annually(KG)
8.21	83.37	26095

6. CONCLUSION

Producing green energy has become one of the major source of energy. Train consume huge fuel or electricity to generate energy. So, by establishing the proposal, it will possible to mitigate the demand of fuel in train. So, emitting CO₂ from train will also mitigate. The amount of power is very encouraging to be used in utility services of train. The system has some limitations that are harsh can be a threat for wind turbine and sunlight does not present all time, static analysis on the system is future work.

References

- V. Nurmanova, M. Bagheri, A. Sultanbek, A. Hekmati, and H. Bevrani, Feasibility study on wind energy harvesting system implementation in moving trains,” *2017 International Siberian Conference on Control and Communications (SIBCON)*, 2017.
- A. S. I. Prof. Bhushan S. Rakhonde, Hybrid Power Generation System Using Wind Energy and Solar Energy , *International Journal of Scientific and Research Publications, Volume 5, Issue 3, March 2015* .
- B. Sindhuja, A proposal for implementation of wind energy harvesting system in trains, *Proceedings of The 2014 International Conference on Control, Instrumentation, Energy and Communication (CIEC)*, 2014.
- NASA Surface meteorology and Solar Energy – Location. Available: <https://eosweb.larc.nasa.gov/cgi-bin/sse/grid.cgi?email=skip%40larc.nasa.gov>, 20-Nov- 2017

Drag coefficient, Available: https://en.wikipedia.org/wiki/Drag_coefficient, 12-Nov-2017
Wagon's Area, Available: <http://www.on-rail.com/1/corporation>, 29-Nov-2017

Air Density, Available: <http://www.myweather2.com/>, 29-Nov-2017

Different Types and Parts of a Horizontal Axis Wind Turbines, https://dolcera.com/wiki/index.php?title=Different_Types_and_Parts_of_a_Horizontal_Axis_Wind_Turbines, 15-01-2018

Solar Panel Efficiency, <https://www.aps.org/>, 25-01-2018

Train Schedule of Bangladesh, <http://www.irfca.org/~shankie/brly/traintime.htm>, 13-02-2018

Power from Diesel Oil, <https://deepresource.wordpress.com/2012/04/23/energy-related-conversion-factors/>, 14-02-2018

Liter to Gallon Conversion, <https://onlineconversion.vbulletin.net/forum/main-forums/convert-and-calculate/1838-converting-1-kg-of-diesel-to-gallons>, 14-02-2018

Carbon Di Oxide Emitting from Diesel, <https://carbonpositivelife.com/co2-per-litre-diesel/>, 14-02-2018

Price of Diesel, http://www.globalpetrolprices.com/diesel_prices/, 14-02-2018]

Mohammad Azazur Rahman is pursuing B.Sc in Electronic and Telecommunication Engineering at International Islamic University Chittagong, Bangladesh. He has two research papers. His research interest includes Power Line Communication.

Mohammad Woli Ullah is an avid learner & academician who is presently serving as a lecturer in Electrical & Telecommunication Engineering in International Islamic University Chittagong. He has also rendered a three year term as a faculty member in ADUST before joining IIUC. Mr. Woli has a strong track record of academic achievement. He has completed his B.Sc & M.Engg in EEE from AIUB. He has also received an MBA in a relevant subject to engineering - MIS- from University of Dhaka. Mr. Woli currently pursuing M.Sc in EEE from BUET. A keen learner of EEE; he has been continuing to learn & teach the subject of his interest. Moreover; a number of research publications have been published in various reputed conference and journals. His research interest includes renewable energy, smart grid, PLC and SCADA.

Muhammad Mostafa Amir Faisal is currently serving as an Assistant Professor in the Department of Electronic and Telecommunication Engineering of International Islamic University Chittagong which is situated in the District of Chittagong, Bangladesh. He has earned His B.Sc and M.Sc in Electrical and Electronic Engineering from Islamic University of Technology (IUT), which is a subsidiary organ of Organisation of Islamic Cooperation (OIC). He has many conference and journal publications. His research interest includes Electromagnetism and Antenna, Wireless Communication, Ethical Engineering, Applied Electronics and Error Correction Coding.

Saif Hannan is currently working as an Assistant professor in department of Electronic and Telecommunication Engineering (ETE) at International Islamic University Chittagong (IIUC), Bangladesh. He completed his M.S degree in Physics from Shahjalal University of Science & Technology (SUST), Sylhet in 2009. His area of research is VLSI, Cellular and Mobile Communication, Optical fiber communication, satellite communication etc. He has several research articles in IEEE sponsored international conferences and few Internal SCI indexed Journals. He is also involved in supervising several undergraduate thesis students.

Abdullah Al Azha is pursuing B.Sc in Electronic and Telecommunication Engineering at International Islamic University Chittagong, Bangladesh.

Muhammad Solaiman Mohim is pursuing B.Sc in Electronic and Telecommunication Engineering at International Islamic University Chittagong, Bangladesh.

Ahmed Afif Monrat is a master student in Erasmus Mundus joint master scholarship program, Pervasive Computing and Communications in Sustainable Development (PERCCOM) at Skelleftea, Sweden. He is an experienced Web Developer with a demonstrated history of working in the academia and skilled in Big Data Analytics, Cloud Computing, RESTful Web Applications, Oracle Database Administration, PHP, and Distributed Computing. His research is focused on disaster management using Big Data Analytics and machine learning. Previously, he has worked as an assistant lecturer in International Islamic University Chittagong (IIUC), Bangladesh.