GENERATION OF POWER BY USING THE WIND ENERGY CREATED BY FAST MOVING TRAIN:

THE CASE OF FUTURE ETHIO-DJIBOUTY RAILWAY

Submitted in partial fulfillment of the requirements for the Degree of Master's in Electrical Engineering for Railway System

By

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SUBMITED TO

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The undersigned have examined the thesis entitled’ **Generation of power by using the wind energy created by fast moving train:The case of future Ethio-Djibouty** ’presented by **Renda Mohammedjuhar**,a candidate for the degree of Master of science and hereby certify that it is worthy of acceptance.

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UNDERTAKING

I certify that research work title" **Generation of power by using the wind energy created by fast moving train: The case of future Ethio-Djibouty**" is my own work. The work has not been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledge.

ABSTRACT

This project is to generate electricity by using wind turbine that can be installed between the sleepers on a track, and as the train passes overhead, the wind drives a turbine to generate electricity. These devices are placed along railway lines, and make good use of an otherwise wasted resource. This system used battery storage, three blades, small wind DC generator and wiring. If the speeds of the train are high the wind speed also high .A train speed of 56m/s will produce 15.24m/s wind speed, which is high enough to generate power. With this wind speed and a blade radius of 0.25metres 1200 turbines produced an output power of 468kW which is enough to power the city

Calculations of wind power generation by the turbine are discussed. Design and model of wind turbine conducted. Simulation of wind power generation is also conducted in MATLAB Simulink. Collection and distribution of power is highlighted. Economical profit of the suggested design is also discussed in detail. The payback period calculations for different scenarios are also discussed at the end.

ACKNOWLEDGEMENTS

First and for most, I would like to thank almighty ALLAH .I would like to express my sincere gratitude to my advisor DR Mengessha Mammo for his support and guidance throughout the completion of the thesis. His unquenchable energy has been both inspiration and motivation for me, and constructive comments and feedbacks given during meetings helped to keep the right track in pursuing the quality work.

I also want to thank my mother, words cannot express how grateful I am to her, for all of the sacrifices that she has made on my behalf, thank you for all wisdom, love and support you give me, thank you for being there for me all the time.

LIST OF ABBRIVATIONS

HAWT Horizontal axis wind turbine

VAWT Vertical axis wind turbine

PMDCG Permanent magnet Direct current generator

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CHAPTER 1 INTRODUCTION

1.1 BACKGROUND

Global warming challenge along with fossil fuels depletion led governments as well as researchers pay it serious attention to the renewable and green energy resources in recent years. Therefore the proportion of vehicles driving on renewable sources of energy is rapidly increasing. In addition, implementation of alternative energy gives an actual opportunity to consumers to become independent from fossil fuel resources.

One of the most abundantly available renewable forms of energy is wind. The economical and ecological return presented by energy provided by wind are the most vibrant reasons behind the attention received by the electrical systems based on wind energy. As we know that the demand of wind energy has increased, a significant amount of effort is being made to produce electricity from new sources of energy [1].

Wind energy is a renewable energy source in all over world. It is sustainable and use of wind energy as an auxiliary source of energy. An idea for generating electrical power by harnessing the wind energy created by the fast moving train and generated power is used to run various electrical equipment in the area simultaneously or by charging DC battery which can used later as a source for electrical equipment.

In the future, civilization will be forced to research and develop alternative energy sources. Our current rate of fossil fuel usage will lead to an energy crisis this century. In order to survive the energy crisis many companies in the energy industry are inventing new ways to extract energy from renewable sources. While the rate of development is slow, mainstream awareness and government pressures are growing. These challenges can be overcome by using renewable energy which is available to us every day. By utilizing this huge amount of resources effectively we can overcome the deficiency of power.

Ethiopia is a country that is very well endowed when it comes to renewable energy resources. Includes wind, geothermal, solar as well as biomss. due to the countries rapid economic growth , and the fact that Ethiopia is serious about transitioning to green economy makes exploiting its its renewable energy resource important.

According to ministry of water irrigation and electricity Ethiopia has the potential of 45 thousand MWhydro-power 5-10 thousand MW geotermal potential and 1000 GW wind energy potential among others .however despite the headway made in exploiting this vast potential still only a small portion of that potential remains harnessed.

Now a day electrical railway become one of the most industrys to use green transport system in the world. Rail transport is a means of transferring passenger and goods on wheeled vehicles running on rail ,also known as tracks. Ethiopia is one of the first African countries to build and owe railway infrastructure in the beginning of early 20th century, with the initiative of Emperor Menelik II and with the assistance of France. It is 784 km in length stretching from the port of Djibouti at the coast of the Red Sea to Addis Ababa, the capital city of Ethiopia. (http://www.trainfrancoethiopien.com/histoire_en.php April 2013).

Railway infrastructure in Ethiopia dated back to 1901 when started to operate from the Port of Djibouti to Dire Dawa. The first road was built in 1903. Air transport and shipping /maritime transport activities started to operate in 1946 and 1964 respectively. In fact, the Ethiopian Airlines is a world class airline and one of the best and the first in the African continent.

High speed moving air is always present around the vehicles. So this project chooses Trains because of their robust design and huge body. High speed trains are run on average speed of 50-65 m/sec, A train moving at 55.88 m/sec would generate a wind speed equivalent to 15.24 m/sec [2] .This is a fact that this mach wind speed would be sufficient for running the turbine and generating electricity. This alternative form of wind energy produced by trains is very unique. The energy generated from this device is produced as a consequence of human activity.

1.2 WIND SYSTEM BASICS

All wind systems consist of a wind turbine, a tower, wiring, and the “balance of system” components: controllers, inverters, and or batteries. Home wind turbines consist of a rotor, a generator mounted on a frame, and (usually) a tail. Through the spinning of turbine blades, the rotor captures the kinetic energy of the wind and converts it into rotary motion to drive the generator. Rotors can have two or three blades and the common wind system is using three blades type. The best indication of how much energy a turbine will produce is the diameter of the rotor, which determines its “swept area,” or the quantity of wind cut by the turbine. The frame is the strong central axis bar onto which the rotor, generator, and tail are attached. The tail keeps the turbine facing into the wind.

1.3 WIND ENERGY

Wind, which is an effect from the uneven heating of the earth’s surface by the sun and its resultant pressure inequalities. Wind energy conversion systems (wind turbines, wind generators, wind plants, wind machines, and wind dynamos) are devices which convert the kinetic energy of the moving air to rotary motion of a shaft, that is, mechanical energy.

The wind energy is converted through friction into diffuse heat throughout the earth's surface and the atmosphere. The earth is non-linearly heated by the sun resulting in the poles receiving less energy from the sun than the equator does. The differential heating powers a global atmospheric convection system reaching from the earth's surface to the stratosphere which acts as a virtual ceiling. Wind energy is the kinetic energy of the air in motion. Total wind energy flowing through an imaginary area A during the time t is:

$$E = \frac{AVt\rho V^2}{2} \qquad 1.1$$

where;

V = wind velocity, and

ρ = air density.

The formula presented is structured in two parts: (A. v. t) is the volume of air passing through A, which is considered perpendicular to the wind velocity; ($\rho \frac{1}{2}v^2$) is the kinetic energy of the moving air per unit volume.

Total wind power is:

$$\frac{E}{t} = \frac{A\rho V^3}{2} \qquad 1.2$$

Wind power is thus proportional to the third power of the wind velocity.

1.4 Statement of Problem

Wind turbines (wind farm) in Ethiopia require generating electrical energy by taking eight times more land space than solar plant. Nodaway alternative uses for the land might be more highly valued than electricity generation. Wind energy is not a constant energy source, the wind is not always blowing, and they generate noise and visual pollution, therefore this research implementing renewable (Wind) energy system along rail road track for future Ethiopian railways. It is the best option because it takes low space; with small turbines moreover the wind is always and easily available as long as the train is running above the turbine. These are independent of seasonal winds having variation in wind speed & direction.

1.5 Objective

The main objective is to develop electricity generation system along rail road track by implementing a wind turbine between sleepers with the aim of contributing to present power generation system as a need of energy is growing continuously.

1.5.1 Specific objective

- Design and model of wind turbine and generator
- Estimation of power generated from the available wind energy.
- Simulation of the overall design and calculate the power output
- Discussion of the economic and ecological profit of implementing wind turbines on the railway track will be discussed.

1.6 The Scopes of this thesis **are**

- To analysis of the output power
- To analyze the suitable turbine and generator use
- Quantity of energy that can be produced.

1.7 Organization of the thesis

This study is organized in seven chapters: The first chapter deals with the background of the project, statement of the problem, objective of the project, delimitation of the project. The second chapter, which follows, describes literature review. The third chapter deals with design and model of wind turbine and generator. The fourth chapter is concerned with the power output calculation. The fifth chapter deal with the simulation of the project .The sixth chapter is about result and discussion. The final chapter presents the conclusion and future work.

CHAPTER 2 LITERATURE REVIEW

2.1 Renewable Sources

Automobile utilizing of renewable sources such as solar energy or bio fuel in car have become a widespread practice, there are several successful projects introducing solar energy into other fields of transportation such as aviation and railways. In fact, to produce the amount of energy equivalent to what is generated by conventional sources the renewable and green sources require significantly larger power plant area. Total land required for different types of energy generation with similar output is as follows:

Nuclear power station – 1.8 GW, 1.7 miles^2;

Wind turbines required to generate – 1.8 GW, 169 miles^2;

Solar plant – 1.8 GW, 21 miles^2 .

In this context, implementation of renewable (Wind) energy on moving train is quite innovative approach. Considering the total fuel consumption of the train, the power generated by available renewable resources seems to be insufficient. Therefore, numerous researches are being conducted in order to investigate possible scenario to reach maximum utilization of alternative energy on the train. [3]

2.2 Wind turbines

A wind turbine is a machine that converts the kinetic energy in wind into mechanical energy. When the mechanical energy is converted to electricity, the machine then is called a wind generator, wind turbine, or wind energy converter.

The wind turbine itself is the primary step to start the design of the wind power generation unit. In order to eliminate any confusion, it is important to primarily clarify the difference between wind turbine and the windmill: the first one converts mechanical energy into electrical, whereas in a windmill the mechanical energy is directly used by machinery.

2.3 Classification of wind turbines

There are broadly three ways to classify the wind turbines: on the basis of the orientation of axis of rotation (vertical or horizontal), on the basis of the component of aerodynamic forces (lift or drag) that power the wind turbine, and on the basis of energy generating capacity (micro, small, medium, or large).

2.3.1Vertical axis wind turbines

There are three most popular designs of VAWTs:

(a) Savonius VAWT,

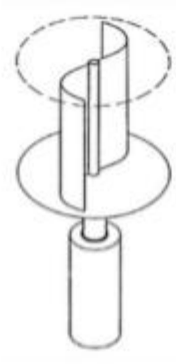
(b) Curved-blade Darrieus VAWT, and

(c) Straight-blade VAWT

(d) gorlove VAWT

Figure 2.1(a)-(c) show Savonius, curved-blade Darrieus, and straight-blade Darrieus VAWT rotors, respectively. Savonius turbines are drag-type while Darrieus turbines are lift-type. In principle, Savonius rotors normally have two cups or half drums attached to a central shaft in opposing directions, as shown in Fig. 2.1(a). The drum, which is against the wind flow, catches the wind and creates a moment along the axis. The aerodynamic torque by the first drum rotates the rotor and brings the opposing drum against the wind flow. The second drum now catches the wind and causes the rotor to rotate even further and thus completes a full rotation. This process continues until there is sufficient wind to turn the axial shaft which is normally connected to a pump or a generator. Savonius turbines generally have poor efficiency (less than 25 %) and that’s why they are not so commercially.

The Darrieus-type VAWTs consists of two or more blades which are attached to a vertical central shaft. These blades can be curved (as shown in Fig. 2.1(b)) or they can be straight (as shown Fig. 2.1 (c)). Irrespective of the curvature, the blades always have airfoil profile which creates aerodynamic lift, when they are exposed to the incident wind. This phenomenon creates moment along the axis and causes the central shaft to rotate, which ultimately runs the generator to produce electricity. The curved-blade Darrieus VAWTs have lower bending stress in the blades as compared to straight-blade Darrieus VAWTs and therefore former is more commercially successful .The gorlove VAWT is showen in fig (d) However, on the small-scale power production, the straight-bladed pitch straight-bladed Darrieus VAWTs don't have self start ability .The variable pitch configuration of the blades allows Darrieus VAWTs to overcome the starting torque problem.The curved blade Darrieus VAWTs have efficiency 35%, the straight blade Darrieus VAWTs have efficiency 30% and the Savonius which uses scoop to catch the wind and efficiency 30%. [4]


(a)


(b)


(c)

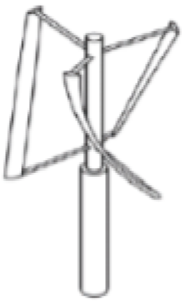

(D)

Fig 2.1 Types of vertical axis wind turbine [4]

Wind turbines can improved by modifying the conventional design, such as pitch and yaw systems to adjust the blades of the turbine according to direction of the wind and enhance the aerodynamic properties of the structure (see Figure 2.2)

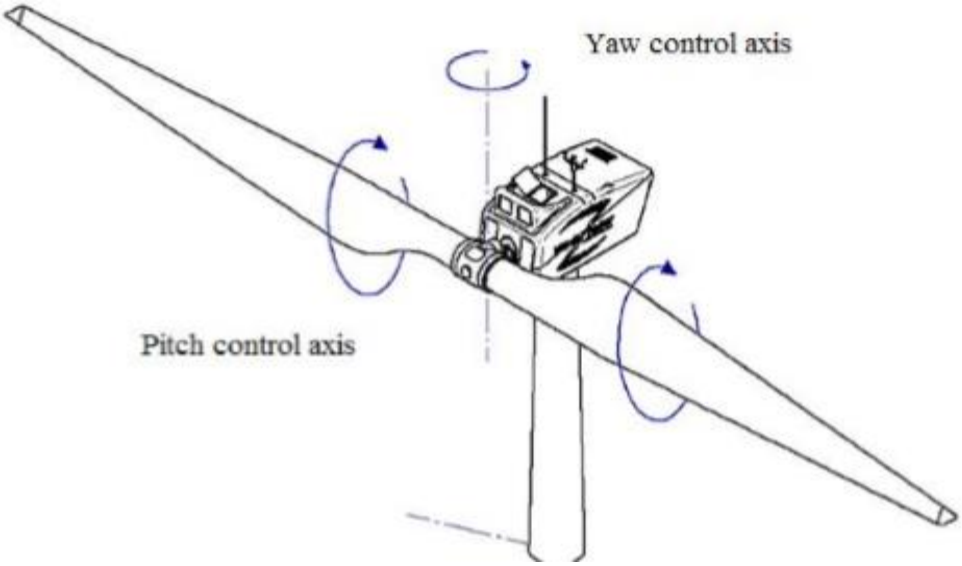


Fig 2. 2 Pitch and yaw system taken from [3]

As it is obvious in Figure 2.2 the pitch and yaw control systems are beneficial in case of HAWT, whereas VAWT does not require systematic adjustment blades angle.

2.3.2 Horizontal axis wind turbines

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.

It is suggested to use VAWT for this study due to following reasons:

- beneficial at high wind speed typical for moving train;
- robust structure as HAWT will produce significantly more air drag;
- HAWT’s blades are more likely to undergo mechanical damage due to high thrust;
- blades of the HAWT must be adjusted to wind direction by using
- pitch system, which is not required for VAWT;
- the starting torque for VAWT is higher compared to HAWT;
- in case of VAWT, additional components such as gearbox and generator are combined into more compact structure

2.4 Drag type and lift type wind turbines

When a flat object is exposed to an incident wind, it encounters a surface force, commonly known as aerodynamics force (Fig. 2.3). The component of the aerodynamic force that is parallel to the flow direction is called drag while the one, perpendicular to the direction of wind, is called lift. Magnitude of the drag force and the lift force are determined by following expressions:

Where a is the platform area (projected area perpendicular to the flow velocity) of the object, p is density of the air, and u is the upstream wind speed and, C_d and C_l are proportional constants called drag and lift coefficients respectively. The constants depend on the ‘aerodynamic quality’ of the object: the better the aerodynamic quality of the object, the higher is the lift coefficient but lower is the drag coefficient, and thus higher the lift force but lower drag force.

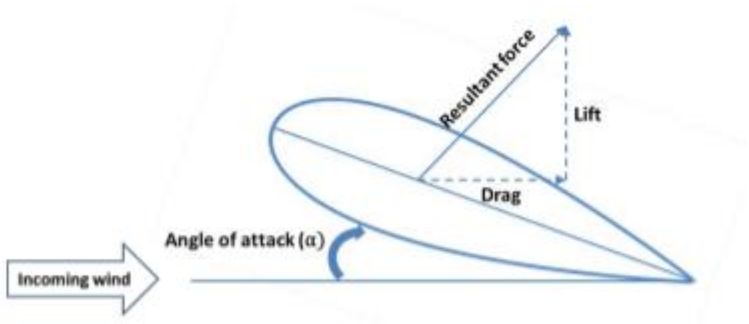


Fig 2. 3 Some basic terminologies related to an airfoil [3]

2.5 Large scale vs. small scale wind turbines

The definition of “small” and “large” scale windmill has remained vague in the literature of wind energy. Small wind turbine was initially defined on the basis of its capability to produce electrical power sufficient enough to cover individual household electricity demands. Lacking any credible unanimous definition, the range for the rated power capacity of small scale wind turbines vary from few watts to few hundred kilowatts. This method small scale wind turbines is used for this method and The generated power is used effectively for lighting and fans in train.

(i) Micro-scale wind turbine (μSWT): rotor diameter   10 cm,

(ii) Small-scale wind turbine (SSWT): 10 cm < rotor diameter   100 cm,

(iii) Mid-scale wind turbine (MSWT): 1 m < rotor diameter   5 m, and

(iv) Large-scale wind turbine (LSWT): rotor diameter > 5 m

2.6 Aerodynamic Model

The wind turbine design parameters considered in the design process are:

- Swept area
- Power
- power coefficient
- Tip speed ratio
- Blade chord
- Types of blade
- Number of blades
- Solidity
- Initial angle of attack

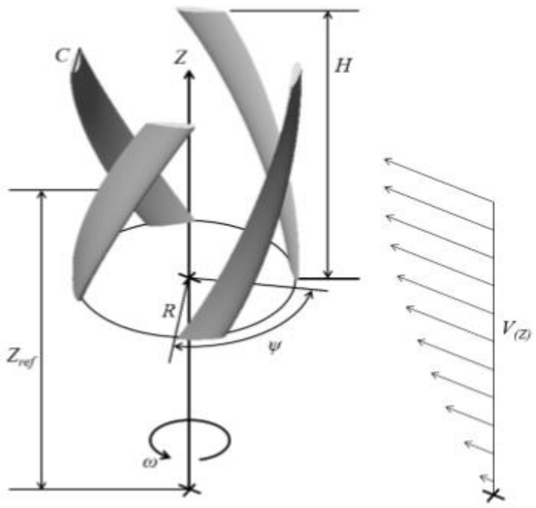


Fig 2. 4 Basic design parameters of the helical vertical wind turbine taken from []

2.6.1 Swept area

The swept area is the section of air that encloses the turbine in its movement, the shape of the swept area depends on the rotor configuration, the swept area of an HAWT is circular shaped while a straight-bladed vertical axis wind turbine the swept area has a rectangular shape and is calculated using .

$$S=2RL \qquad 2.1$$

where

S is the swept area [m^2],

R is the rotor radius [m], and

L is the blade length [m].

The swept area limits the volume of air passing by the turbine. The rotor converts the energy contained in the wind in rotational movement so as bigger the area, bigger power output in the same wind conditions.

2.6.2 Power

Power production from a wind turbine is a function of wind speed. The relationship between wind speed and power is defined by a power curve, which is unique to each turbine model and, in some cases, unique to site-specific settings. In general, most wind turbines begin to produce power at wind speeds of about 4 m/s (9 mph), achieve rated power at approximately 13 m/s (29 mph), and stop power production at 25 m/s (56 mph). Variability in the wind resource results in the turbine operating at continually changing power levels. At good wind energy sites, this variability results in the turbine operating at approximately 35% of its total possible capacity when averaged over a year. The amount of electricity produced from a wind turbine depends on three factors: [18]

1) Wind speed

The power available from the wind is a function of the cube of the wind speed. Therefore if the wind blows at twice the speed, its energy content will increase eight-fold. Turbines at a site where the wind speed averages 8 m/s produce around 75-100% more electricity than those where the average wind speed is 6 m/s.

2) Wind turbine availability

This is the capability to operate when the wind is blowing, i.e. when the wind turbine is not undergoing maintenance.

3) The way wind turbines are arranged

Wind farms are laid out so that one turbine does not take the wind away from another. However other factors such as environmental considerations, visibility and grid connection requirements often take precedence over the optimum wind capture layout.

2.6.3 Power coefficient

It is defined as the amount of mechanical power produced by a wind turbine against the total available wind power. Sometimes, it's also called coefficient of performance and mathematically it is calculated using following expression .

$$C_P = \frac{Pmech}{\frac{1}{2}\rho\pi r^2 u^3} \qquad 2.2$$

where

P_{mech} is the mechanical power generated by the wind turbine,

ρ is the density of the wind,

r is the tip radius by the rotor and

u is the free wind speed.

The denominator term ($1/2\ \rho\pi r_t^2\ U^3$) of equation 2.2 denotes the total available wind power passing across the swept area of the wind turbine rotor.

There is a theoretical limit in the efficiency of a wind turbine determined by the deceleration the wind suffers when going across the turbine. For HAWT, the limit is 19/27 (59.3%) and is called Lanchester-Betz limit (Tong, 2010, p. 22). For VAWT, the limit is 16/25 (64%) (Paraschivoiu I. , 2002, p. 148).

This power coefficient only considers the mechanical energy converted directly from wind energy; it does not consider the mechanical-into-electrical energy conversion, which involves other parameters like the generator efficiency.

2.6.4 Tip Speed Ratio (TSR)

The power coefficient is strongly dependent on tip speed ratio it's of vital importance in designing a wind turbine. It's a ratio between the tangential speeds of tip of blade to the actual speed of wind. It is related to efficiency

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. The 3 -blades turbine generated the highest value of TSR and Cp than other. Turbine is designed with optimal TSR to extract as much power out of the wind as possible.

$$\lambda = \frac{R\omega}{V} \tag{2.3}$$

Where

λ is Tip speed ratio

R is radius of the turbine , and

V is wind speed

All wind turbine rotors have an optimum tip speed ratio with maximum power. The optimal ratio is related to the change of the incoming wind speed. [5]

2.6.5 Blade chord

The chord is the length between leading edge and trailing edge of the blade profile. The blade chord length (C) can be calculated using the solidity. The chord length is the length of the airfoil and is an important design variable because the generated torquechanges according to the chord length.

2.6.6 Types of Blade

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.

2.6.7 Number of blade

It has a direct effect in the smoothness of rotor operation and compensate cycled aerodynamic loads and therefore, four and three blades maybe chosen. The limitation of available power in the wind means that the more blades there are, the less power can extract. The consequence of this is that each blade must be narrower to maintain aerodynamic efficiency, A bigger number of blades lead to a bigger deceleration of the air, and this effect is greater than the increase in torque that can be produced having more blades. In this case there is no a problem of wind pressure. As long as the train is moving above their will be wind speed. High wind pressure is generated by speeding train, which directly in contact with the blade of turbine and hence the rotor rotates which generate electricity.

2.6.8 Solidity

Solidity (σ) is an important variable that determines the performance of wind turbines. Solidity is defined as the ratio of the total projected area (NC) of the rotor blade to the rotational area of the wind turbine rotor. The projected area is the projection in the vertical section of the rotating shaft and can be expressed as

$$\sigma = \frac{NC}{2\pi R} \qquad 2.4$$

where

N is the number of blades,

C is the blade chord,

This formula is not applicable for HAWT as they have different shape of swept area.

2.6.9 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 ^{o}, 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 create the best rotation .To increase wind turbine blade efficiency, rotor blades needs to have aerodynamic profile to create lift. The angle of attack can be expressed as Equation 2.5.

$$\alpha = \tan^{-1}(\frac{\sin\theta}{\cos\theta + \lambda}) \qquad 2.5$$

2.7 The Overall efficiency Power coefficient C_P

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 represents the combined efficiency of various wind power system components which includes shaft bearing and gear train.

$$C_{P=}\frac{actual\ electrical\ power\ produced}{wind\ power\ in\ turbine} = \frac{pout}{pin} \qquad 2.6$$

where

C_p is overall turbine efficiency

Pout is electrical power out

Pin is wind power in

Cp value represents the part of the total available power that is actually taken from wind, which can be understood as its efficiency.

2.8 Wind turbine generator

The electrical machine most commonly used for wind turbines applications are those acting as generators, with synchronous generators and induction generators. Being commonly used in large wind turbine generators, while smaller wind turbines tend to use a low speed DC generator or dynamo as they are small, cheap and a lot easier to connect up.

2.8.1 DC generators

These are used in applications like battery charging, welding, ordinary lightening applications etc. they are small, cheap and a lot easier to connect up.

2.8.1.1 Permanent Magnet DC Generator

The PMDCG has several advantages:

- They are small and light in size.
- As these generators do not require field windings, they do not have field circuit copper losses. This increases their efficiency.
- less maintenance because it does not have any rotor current (no field)
- Can also be used without a gearbox. Which takes more space, with more power loss and increased costs
- They are preferred in small scale wind turbines, also in large MW applications. can operate at low rotational speeds

CHAPTER 3 METHODOLOGY

In this section, the rotor, blade and wind turbine design parameters are described as well as the model used to calculate its aerodynamic performance.

Selection of material for vertical axis wind turbine should follow below criteria.

- It can withstand pressure generated due to wind velocity
- It can be low in weight.
- It should have high resistance to corrosion, wear and atmospheric conditions.
- It can be easily available.
- Weight to strength ratio is as high as possible.

3.1 Design Constraints

This thesis requires a lot of parameters to be taken into account, because the helical turbine design has numerous variables that need to be optimized, such as the blade profile, the inclination angle, twist angle, chord length, height, and width.

As for sustainability, the helical design puts a lot of cyclic stress over the turbine blades, thus, not all materials are suitable for the design, metallic design may not be compatible with such loads, and thus, light materials are more suited for this design as they are less prone to fatigue caused by cyclic stresses.

As for manufacturability, this project does not have many constraints, blades are made out of ductile material such as aluminum, steel or composite material and the energy is transmitted to a battery, both of which can be easily manufactured and obtained.

The turbine requires a box to protect against mechanical damage and a small opening to allow wind hit the blade.

3.2 Design Methodology

The parameters fall primarily into two categories, namely those governed by the geometry of the turbine, and those governed by the flow field in which the turbine is designed to be placed. In general the parameters governed by the flow field in which the turbine is to be place, are fixed, the changing parameters are wind speed and the density of the air .According to Qian and Luparini a train moving at 56 m/sec would generate a wind speed equivalent to 15.24 m/sec and the air density can be calculated using equation 3-1.

$$\rho = \frac{p}{RT} \qquad 3.1$$

where

ρ is air density

R is Gas constant which is 287.05 J K/ Kg

T Temperature of air in Kelvin

density can be taken 1.12 Kg/m^3

3.2.1 Helical turbine

In this case helical blades were selected for low noise and low output flactuation. The helical type is advantageous in that the fluctuation range of the output is smaller than that of the conventional Darrieus blades, and the self-starting performance is better. It also has less mechanical load and less noise than a Savonius rotor, which is a drag-type rotor. The blades are obviously designed to rotate about a central axis within the cylinder housing.

The helical turbine, also known as the Gorlov turbine was the choice of design. Figure 3 shows the turbine.

Fig 3. 1Fig 3.1 Gorlov Turbine taken from [7]

For VAWT, the efficiency limit is 16/25 (64%) ,Therefore assuming that $Cp \approx 0.55$.It was found that the tip speed ratio for Gorlov turbine falls between 2-2.5

The natural tip speed ratios of the Gorlov helical turbine were found to fall within the range from 2 to 2.5 in almost all resources used, except Shiono et al. found the range to be just below 1 to 2.5. If this lower range is considered to be for not quite optimized circumstances and ignored, the tip speed ratio range of 2 to 2.5 can be used to predict possible expected angular velocities for the turbine using the relationship [7]

$$\lambda = \frac{R\omega}{V} \qquad 3.2$$

where:

λ: Tip speed ratio,

R: Turbine radius,

ω: Angular velocity,

V: Average air velocity.

Rearranging the above equation yields

$$\omega = \frac{\lambda V}{R}, \qquad 3.3$$

As mentioned above

R= 0.5/2=0.25 m,

V= 15 m/sec,

$$\lambda average = \frac{2.5+2}{2},$$

λ = 2.25.

Thus the equation becomes

$$\omega = \frac{2.25X15}{0.25} = 135 \text{ rad/sec}$$

The torque of the turbine can be calculated using the following equation

$$T = \frac{\frac{1}{2} CP\rho AV^3}{\omega}, \qquad 3.4$$

where:

A: $Area$ = L ×d = 1×0.5 = 0.5 m^2

Cp: Power coefficient,

ρ: Air density,

V: Wind velocity,

ω: Angular velocity.

Then the torque becomes:

$$\mathrm{T} = \frac{0.5X0.55X1.12X0.5X15^3}{135} = 3.85\mathrm{N.\,m}.$$

The power of the turbine can be calculated as equation 3.5

$$P = \frac{1}{2}\rho A V^3 \quad , \tag{3.5}$$

$$P_{flow} = 0.5 \, X 1.12 X 0.5 X 15^3,$$

$$=945.$$

Pturbine=Pflow x Cp,

Pturbine=945×0.55 = 519.75W.

Table 3. 1 The power at different wind speeds

Velocity (m/s)	Diameter (m)	Length (m)	Area (m^2)	Power (W)
9	0.5	1	0.5	112.26
10	0.5	1	0.5	154
12	0.5	1	0.5	266.1
15	0.5	1	0.5	519.75

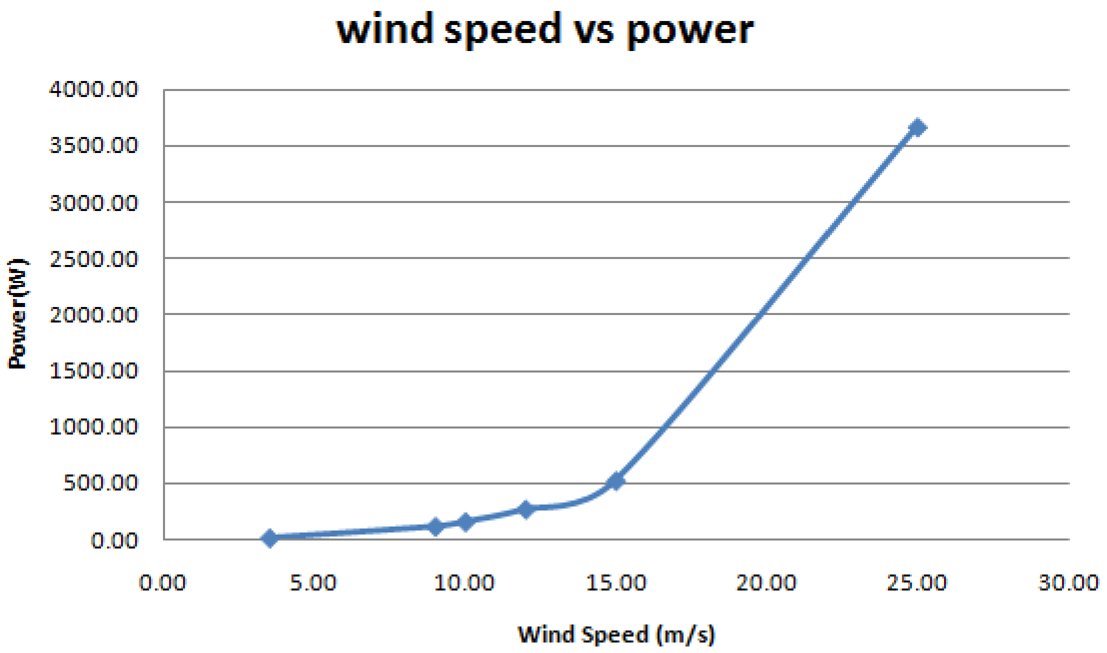


Fig 3. 2 .Power at different speeds

According to [7] the efficiency and controllability are affected by the solidity of the turbine, solidity is defined as σ, the developed surface area of all blades divided by the swept area of the rotor, it was found that at 0.15, as a good compromise between controllability and rotor efficiency and it is calculated by using equation (3.6) shown below. A turbine with high solidity allows keeping the optimized turbine rotational velocity relatively low, which minimizes the rotor vibrations and maximizes the aerodynamic efficiency

$$\sigma = \frac{NC}{2\pi R} \qquad 3.6$$

where:

σ: The solidity,

N: Number of blades ,

c: Chord length ,

R: Radius of the turbine,

Rearranging equation (3.6) yields

$$C=\frac{\sigma 2\pi R}{N} \qquad 3.7$$

$$\frac{\mathbf{0.15X2X3.14X0.25}}{\mathbf{3}},$$

$$\approx 0.08,$$

Table 3. 2 Turbine specifications

Items	Description
Rotor type	Helical
Rated Power output	1000 W
Rated wind speed	15m/sec
Power coefficient	0.55
Length of the turbine	1m
Diameter of the turbine	0.5
Swept area	0.5m^2
Aspect ratio	2
Rotor Radius	0.25
Rotor height	1m
Angular velocity	135 rad/sec
Torque	3.85 Nm
Solidity	0.15
Chord length	0.08
Number of blades	3
Airfoil	NACA0018

3.2.3 Material and manufacture

Steel and aluminum have been considered due to their machinebility, strength and availability. While the density of steel is greater than that of aluminum, allowing weight reduction for the turbine, steel has greater strength and lower cost. So it is obvious material of choice for the turbine body since it has the qualities of good machinability and weldability, high strength and is readily available.

3.3 Wind turbine power output

The figure below shows a sketch a how the power output from a wind turbine varies with steady wind speed

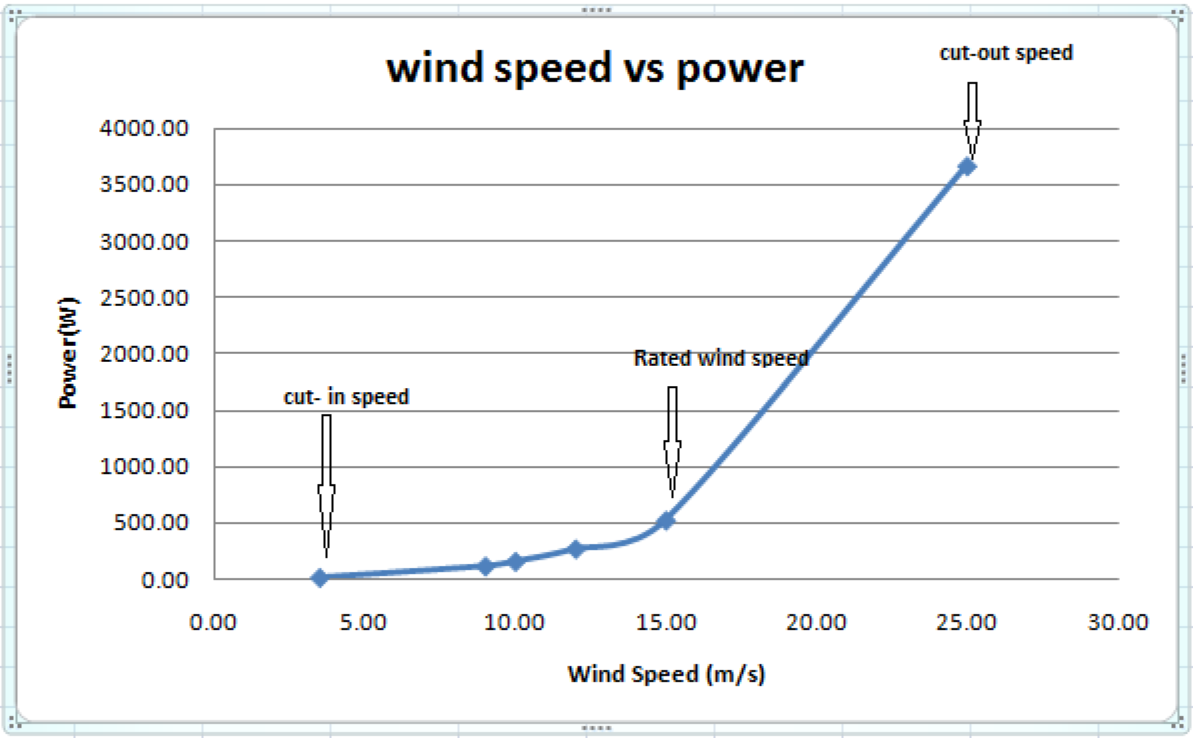


Fig 3. 3 wind speed power output

Hear there is no need of pitch control for constant power output because the wind speed is known and constant.

3.3.1 Cut-in Speed

The cut-in speed of a wind turbine is defined as the minimum wind speed at which the wind turbine starts on its own and generates some usable power. Is typically between 3 and 4 metres per second

The turbine will start generating useful power above the cut in speed. The cut in turbine speed can be calculated using equation 3.8.

$$\omega cutin=\frac{TSR\, Vcutin}{R} \qquad 3.8$$

3.3.2 Rated Speed

The rated speed of a wind turbine is defined as the minimum wind speed at which the wind turbine generates its indicated rated power. As the wind speed rises above the cut-in speed the level of electrical output power rises rapidly as shown in fig 3.4 however typically somewhere between 12 and 17 meters per second the power output reaches the limit that the electrical generator is capable of this limit to the generator output is called the rated power output at higher wind speed the design of the turbine is arranged to limit the power to this maximum level and there is no further rise in the output power. How this is done varies from design to design but typically with large turbines, it is done by adjusting the blade angles so as to keep the power at the constant level.

3.3.3 Cut-out Speed

The cut-out speed of a wind turbine is the maximum wind speed up to which the wind turbine should operate. This is required as a safety feature to protect the wind turbine from being damaged at the high wind speed. As a result braking system is employed to bring the rotor to standstill. The cut –out speed is usually around 25 meters per second.

3.4 Permanent magnet generator

Permanent magnet generator (allows to eliminate using gearbox), The generator is the 12v model which is capable of more than 1 kW with sufficient Wind speeds ,not longer than 25cm.

3.5 Implementation

After the literature review, it is found that Gorlov helical turbine is the most efficient and Lightweight. In addition, it is capable of generating the needed amount of energy. The turbine consists of three blades that will be attached on a shaft that will be connect to DC permanent magnet generator. Finally, the whole system will be puted on the metallic cylinder with vents, which allow air to flow through and rotate turbine blades housed inside and installed between the railway track sleepers, the metallic box will buried half.

Fig 3. 4 Devise between the sleepers on track taken from [3]

3.6 Constriction

3.6.1 Box

It should be a durable metallic cylinder with vents, which allow air to flow through and rotate turbine blades housed inside. The box contains all the mechanical components required for harnessing, changing supplying wind power. It is designed to be installed within the actual railing track itself.

3.6.2 Shaft

A shaft is a rotating machine element, usually circular in cross section, which is used to transmit power from one part to another, or from a machine which produces power to a machine which absorbs power. The material normally used is mild steel, when high Strength is required, an alloy steel i.e. nickel, nickel-chromium etc. are used. Shaft are generally formed by hot rolling & finished to size by cold drawing or turning & grinding.

Fig 3. 5 shaft

3.6.3 Ball bearings

A ball bearing is a type of rolling- element bearing that uses balls to maintain the separation between the bearing races. The purpose of ball bearing is to minimize rotational friction & support radial and axial load. It achieves this by using at least two races one race is stationary and the other is attached to the rotating assembly. As one of the bearing races rotates it will cause the balls to rotate. Because the balls are rolling, they have a much lower coefficient of friction than that of two surfaces sliding against each other.

Fig 3. 6 ball bearing

3.7 Unit Construction

This wind turbine is basically a non-conventional energy generation system. This inversion relates to generating electricity by pressurized wind by fast moving vehicle channeling the induced wind in the direction of wind turbine. A fast moving train compresses air in front of it, pushes air towards sides i.e. creating vacuum at its rear & move forward

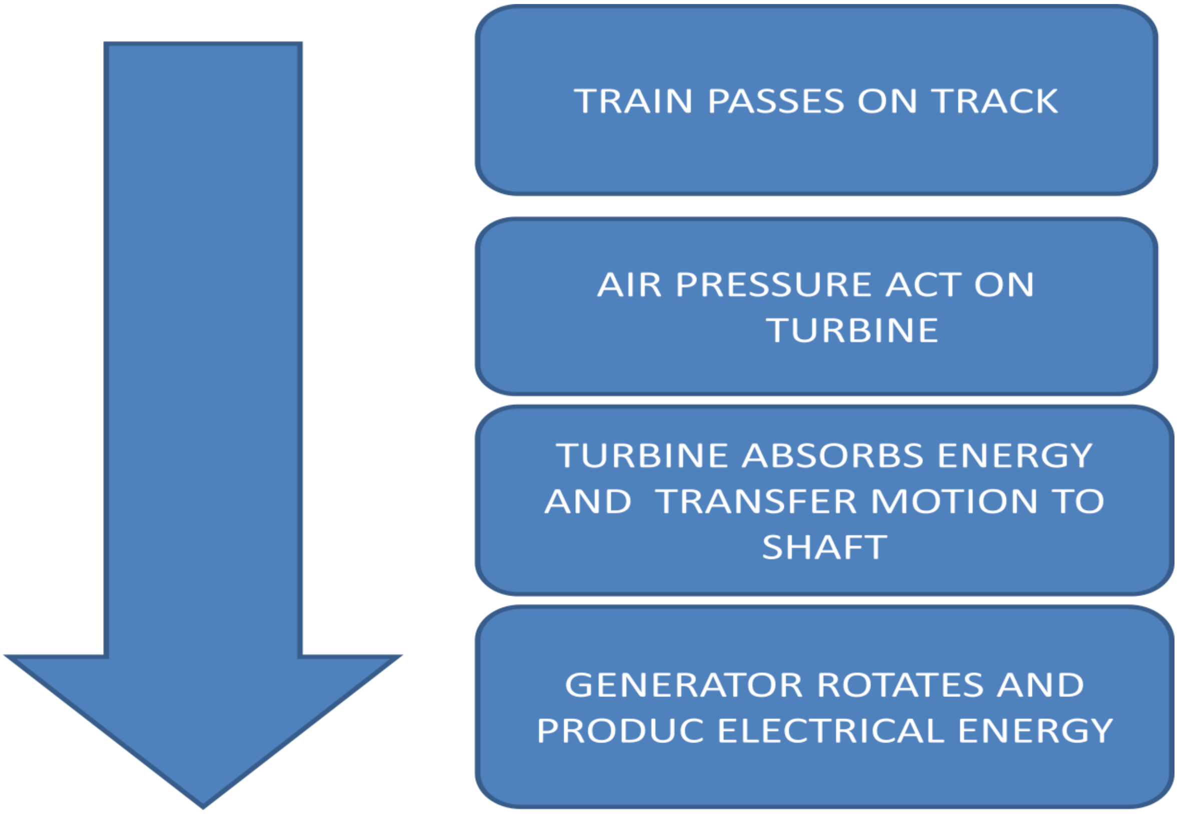


Fig 3. 7 block diagram of the system

To fit the box on the tracks, some work has to be done on them

- Firstly, concaves have to be constructed in cement between each of two sleepers.
- Two brackets then have to be placed on two sides of the concaves.
- The brackets have to be examined to ensure that they are well fixed.
- The box is then set upon the tracks.[8]

3.8 collection and distribution of wind power

3.8.1 Connection of multiple wind turbines

Choosing wiring the turbines whether in series or parallel is the first thing to decide. If we are connecting the turbines in series, connect the wires of the turbines from positive to negative making one continuous loop through the circuit. If we are connecting the turbines in parallel, connect each positive wind turbine wire(positive wire from the wind generator) individually to the positive input connection provided in the combiner box ,connect each negative wind turbine wire individually to negative input connection provided in the combiner box.

In this case we connect the turbines in parallel. The advantage to wiring turbines in parallel is that doing so produce an additive effect. While voltage remains the same the current increases with each additional turbine

When charging a battery with a permanent magnet DC generator, the generator rpm first has to rise to the point where its output voltage reaches the battery terminal voltage. As soon as the generator exceeds that voltage, current starts to flow into the battery, and the effort required to turn the generator (i.e. input torque) increases. As long as that amount of torque can be supplied by whatever is turning the generator, the battery will continue to charge.

As soon as the battery becomes fully charged, no more charging current will flow, and the load disappears. If the generator continues to be driven, then the output voltage, with no load, will rise, and that could damage the battery unless limited by a voltage regulator.

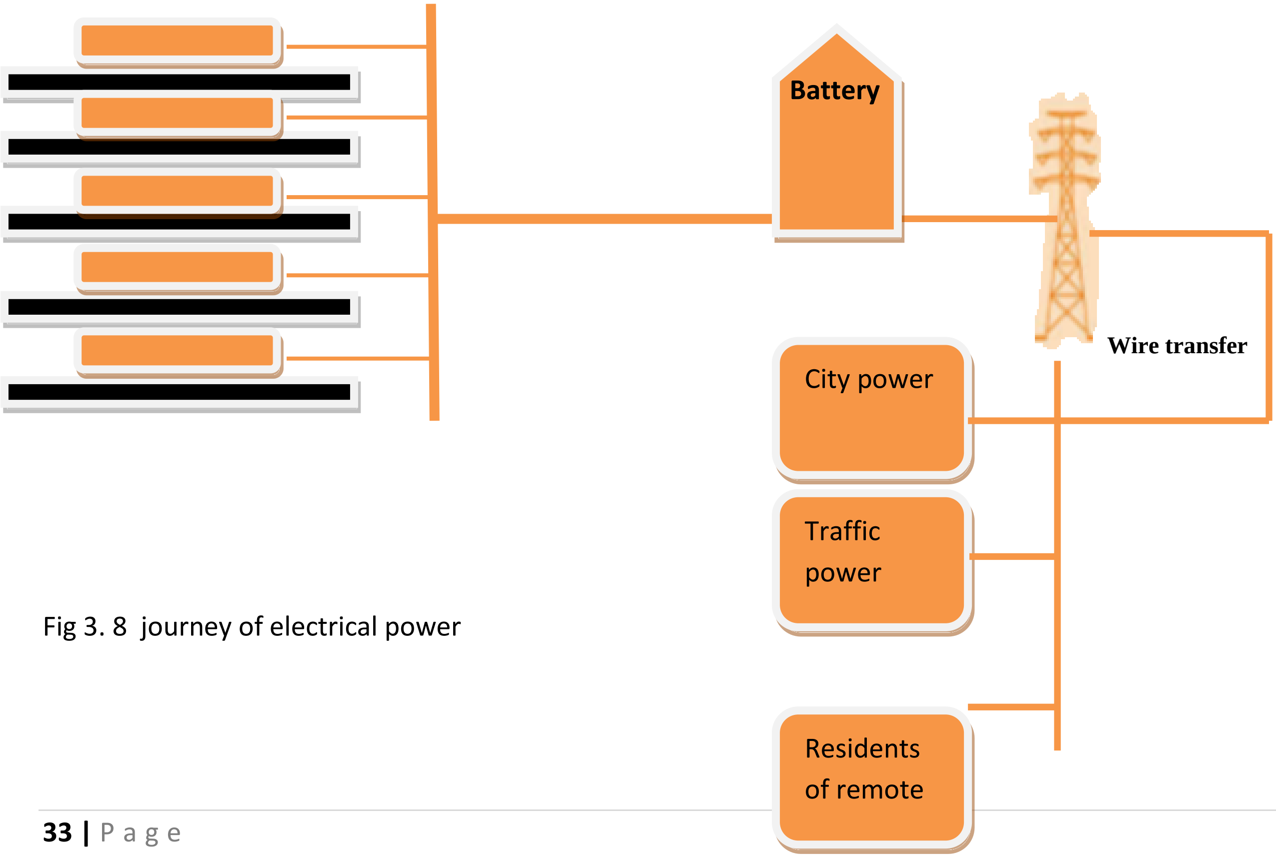


Fig 3. 8 journey of electrical power

CHAPTER 4 POWER CALCULATION

4.1 Wind turbine output power

As anyone living near railway tracks will tell you ,speeding trains generate quite a bit of wind as they whoosh past. The power generation system is utilizes The kinetic energy of this wind flow induced by the train and effectively utilize to generate power on a larger scale.

A train moving at 56 m/sec would generate a wind speed equivalent to 15.24 m/sec wind blowing with such speed will let a normal wind power generator harness about 3500W of power. if a train is about 200m long, running at the pace of 83.6 m/sec and it moves along a 998 meter railway track in about 18 seconds, the power generated in this small period by the boxes laid on the tracks will be 2.6 kW. Qian and Luparini estimate that about 150 box devices could be accommodated along 998 meter railway track [8]

The equation for wind power (P) is given by eq 4.1

$$p = 0.5\rho A C p V^{3} N g \qquad 4.1$$

where,

ρ = Air density in kg/m3, average value for current location

ρ = 1.12 kg/m^3 [9];

A = Rotor swept area (m^2). (Which is equal to the length of the blades times the rotor diameter)

Cp = Coefficient of performance, Cp = 0.55 is often used in this type of calculations as discussed in chapter three

V = wind velocity (m/s) =15.24 m/sec

Ng = generator efficiency = 0.7, this concept works without transmission. If a transmission with efficiency of 0.95 was to be included this means that Ng = 0.95 x 0.7 [10];

$$A = 2RL, \qquad 4.2$$

$$2\times0.25\text{m}\times1\text{m}=0.5\text{m}^{2.}$$

Considering the average speed of a train is 56 m/sec so it would generate wind speed equivalent to 15.24 m/sec

4.2 Model passenger

The power generated by a single unit is

Passenger train

$$P=0.5\times1.2\times0.5\times0.55\times15.24^3\times0.7 = 408 \text{ Watt.}$$

If the train length is 800m, the distance between each of 2 sleepers is 660mm, so there are 150 units in 1000m long railway track, 120 in 800 meter long rail so a train has a capacity to rotate 1200 turbines

Therefore the power produced by the whole system is

$$408\times1200=490\text{kW.}$$

For example a train runs from Addis Ababa to Dire Dawa is 473km and if a train speed is 56 m/sec traveling for 6 hours the energy generated will be

$$49{,}005\times2.5=1224 \text{ kWh per day}$$

3.3 Model Freight

For the freight train with speed of 33 m/sec would generate a wind speed equivalent to 9 m/sec

$$P=0.5\times1.12\times0.5\times0.55\times9^3\times0.7 = 84\text{Watt}$$

Power produced by the whole system is

$$84\times1200=101\text{kW}$$

$$101\times4=404 \text{ kWh per day}$$

3.4 Actual passenger

The power generated by a single unit by is

Passenger train

$$P=0.5\times1.12\times0.5\times0.55\times4.6^{3}\times0.7 = 11.2 \text{ Watt}$$

If the train length is 800m, the distance between each of 2 sleepers is 660mm, so there are 150 units in 1000m long railway track, 120 in 800 meter long rail so a train has a capacity to rotate 1200 turbines

Therefore the power produced by the whole system is

$$11.2\times1200=13\text{Kw}$$

For example a train runs from Addis Ababa to Dire Dawa is 473Km and if a train speed is 33.4m/sec traveling for 7.5 hours the energy generated will be

$$13\times7.5=101 \text{ kWh per day}$$

3.5 Actual fright

For the freight train with speed of 22.2 m/sec would generate a wind speed equivalent to 6 m/sec

$$P=0.5\times1.2\times0.5\times0.55\times4.6^{3}\times0.7 = 11.2\text{Watt}$$

Power produced by the whole system is

$$25\times1200=13\text{kW}$$

$$13\times7.5=101 \text{ kWh per day}$$

CHAPTER 5 SIMULATIONS

5.1 Simulation parameters

There are several parameters which have impact on the power output. Therefore, in order to conduct realistic simulations, the number of input values was increased. For instance, it was decided to simulate the route connecting two cities Addis Ababa and Dire Dawa, due to lack of information about the route. Taking three stations Addis Ababa,Adama and Dire Dawa, a significant change in train speed has been taken into account.

There are passengers and freight trains running between Addis Ababa and Dire Dawa, and the difference is in the number of stops (stations) and speed of the train performs. It should be mentioned that I took the information of the route layout plus the location of the stations is available from internet as well as by attending in person at furi ticket office (station).

Km			
0	Addis Ababa Furi-Lebu	Depart	8:00
98	Adama	Arrive	09:41
		Depart	9:46
446	Dire Dawa	Arrive	15:35

Fig 5. 1 Route (Passenger) Addis Ababa-Djibouti,

The tables below are display names of the stations, arrival and stopping time for the different speed scenario.

1. for Actual scenario

2. for model scenario

All these data will be used as input values in MATLAB Simulink models.

5.1.1 Actual scenario

Addis Ababa – Dire Dawa (446km, 3 stations) passenger:

Trip duration: 7 hours 35 minutes = 27,300 seconds

Speed: 17 m/sec

Stations	Time	Length(HH:M)	Stop (Min)
Addis Ababa(FuriLabu)	08:00	-	-
Adama	09:41	1:41	5
Dire Dawa	15:35	5:54	-

Table 5. 1 Actual Train Parameters

Addis Ababa – Dire Dawa (446km, 3 stations) fright:

Trip duration: 7 hours 35 minutes = 27,300 seconds

speed: 17 m/sec

Stations	Time	Length(HH:MM)	Stop (Min)
Addis Ababa(FuriLabu)	08:00	-	-
Mojo	09:30	1:30	10
Dire Dawa	15:40	6:05	-

Table 5. 2 Actual Train Parameters

5.1.2 Model scenario

Addis Ababa – Dire Dawa (446km, 3 stations) passenger:

Trip duration: 2 hours 21 minutes = 8400 seconds

speed: 56 m/sec

Stations	Time	Length(HH:MM)	Stop (Min)
Addis Ababa(FuriLabu)	08:00	-	-
Adama	08:31	0:31	5
Dire Dawa	10:26	1:55	-

Table 5. 3 Model Train Parameters

Addis Ababa – Dire Dawa (446km, 3 stations) fright:

Trip duration: 4 hours = 14,400 seconds

speed: 33 m/sec

Stations	Time	Length(HH:MM)	Stop (Min)
Addis Ababa(FuriLabu)	08:00	-	-
Mojo	08:39	0:39	10
Dire Dawa	12:10	3:31	-

Table 5. 4 Model Train Parameters

It's better to not put the wind turbine on the bridge and viaducts because of safety purpose .it may put an additional load on the bridge but because of absent of information that the train reaching time I neglect it and near to the stations also we didn't put the units because the train decries its speed to stop and also to accelerate.

The stopping distance of a train can be calculated as

$$S=\frac{V^2}{2\mu g}, \qquad 5.1$$

The friction coefficient for steel to steel contact is 0.74

$$S=56^2 /2\times0.74\times9.81,$$

216 m.

So the train has to apply braking 216m back before reaching and after reaching to each station.

Since the time parameter is measured in seconds, the corresponding simulation times for the actual and the model scenario in Simulink are 27,300 and 8,400 ,14,400 seconds respectively.

The Figure 5.3 illustrates the MATLAB Simulink model of the system. It should be mentioned, that wind speed is a variables that change over the time, and are presented as matrices. The MATLAB code was written in order to create these matrices and convert them into Simulink readable .mat files.

Basically, the wind speed is m×2 matrices, where m is the duration of the trip in seconds.

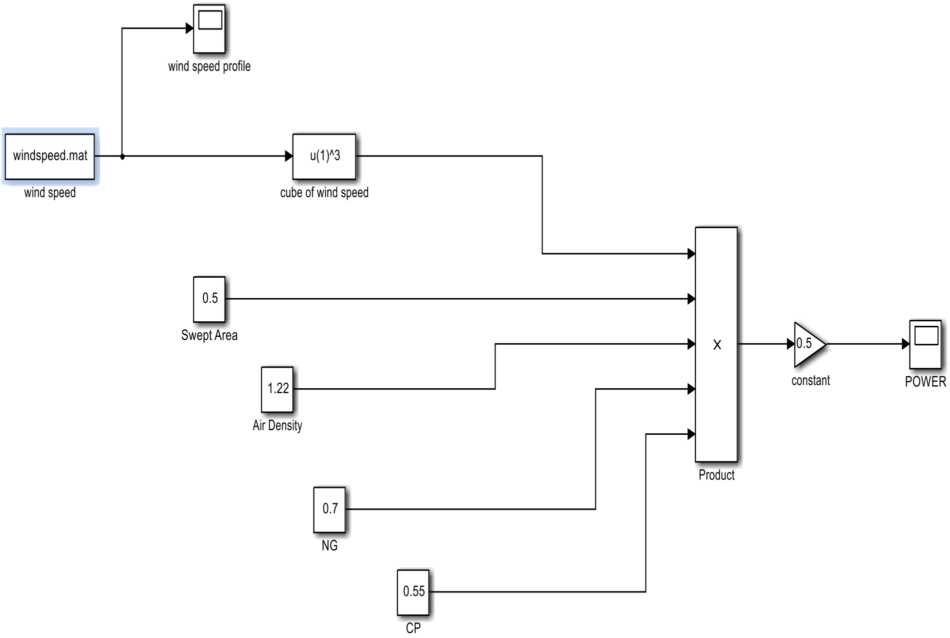


Fig 5. 2 MATLAB Simulink model

CHAPTER 6 RESULTS AND DISCUSSIONS

6.1 Software simulation results

The wind speed and generated output power are displayed in Figures 6.1 through 6.8 Change in wind speed has a notable impact on output power value. Nevertheless . Due to absence of information from continuous monitoring of train speed, 56m/s ,17m/s and 33 m/s were taken as maximum wind speed for model, actual passenger and freight speed accordingly, whereas assuming future trains are capable of reaching the velocity of about 56 m/s.

The acceleration and deceleration values of 1 m/s2 for model passenger ,0.28 m/s2 for actual passenger and freight and 0.58m/s2 for model fright fast , necessary stopping distance were assumed based on standards and according to train’s moving speed and length[11]. The time required for train to start deceleration and stop is calculated as follows:

Tstop = 56 m/s /1 $m/s2$ = 56 (model passenger)

Tstop = 17 m/s /0.28 $m/s2$ = 61 s (actual passenger and freight)

Tstop=33m/s/0.58m/s2=57 s (model fright)

The output power profiles display the power at the turbine output, and its average value during train movement is equal to 468160 W for model passenger, 96342 W for model, 13410 W for actual passenger and 13264 W for actual fright respectively. These are energy generated during one hour of operation, and the net power is basically calculated by multiplying these numbers by duration of the trip. Total power calculations are presented in next section of this chapter.

However, it should be noted that during stop times of the train the wind speed and the power at the turbine output will become zero. And when the train starts movement the power will increase gradually depending on the installed number of unites and become constant.

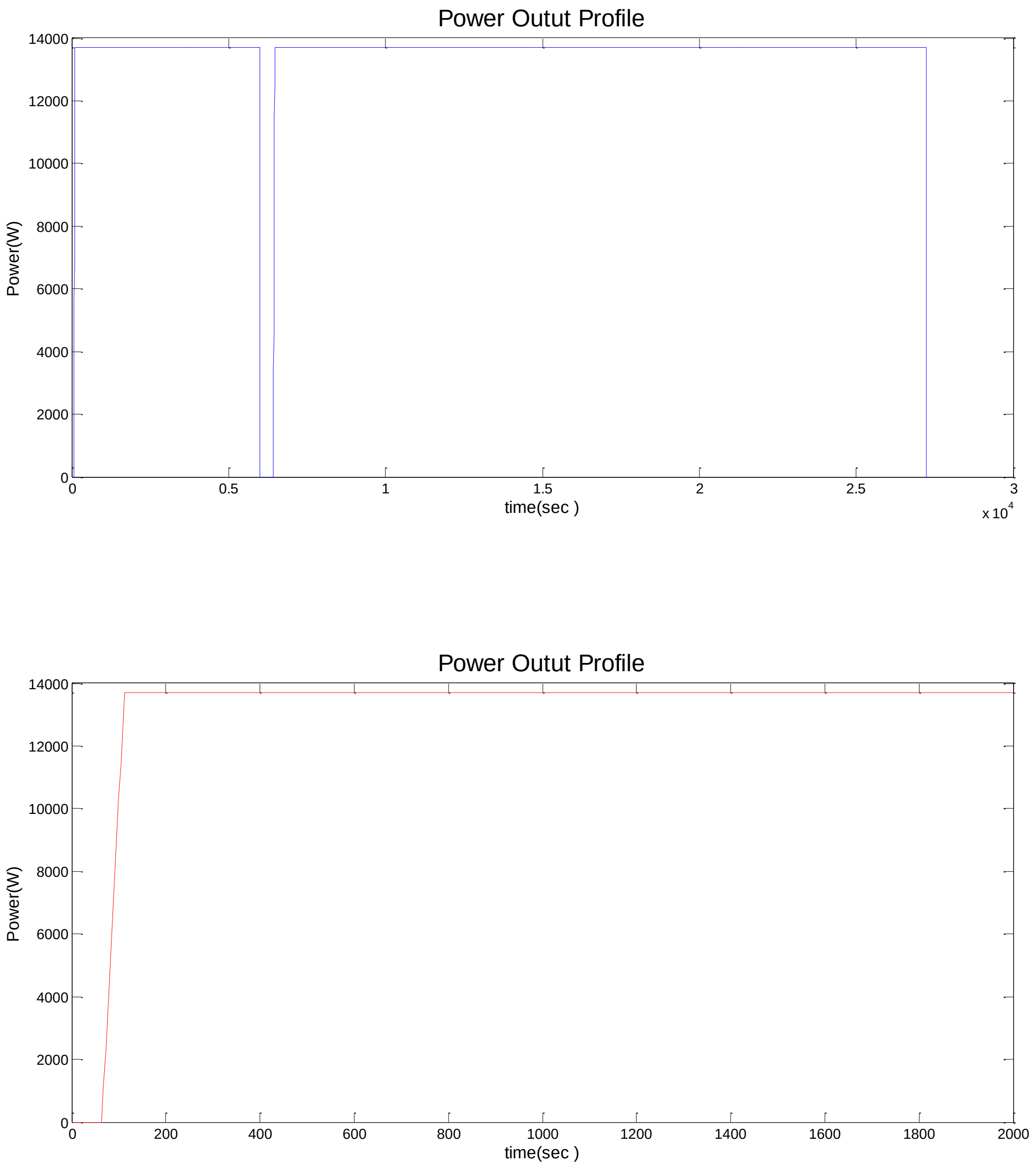


Fig 6. 1 Output power profile for actual passenger speed

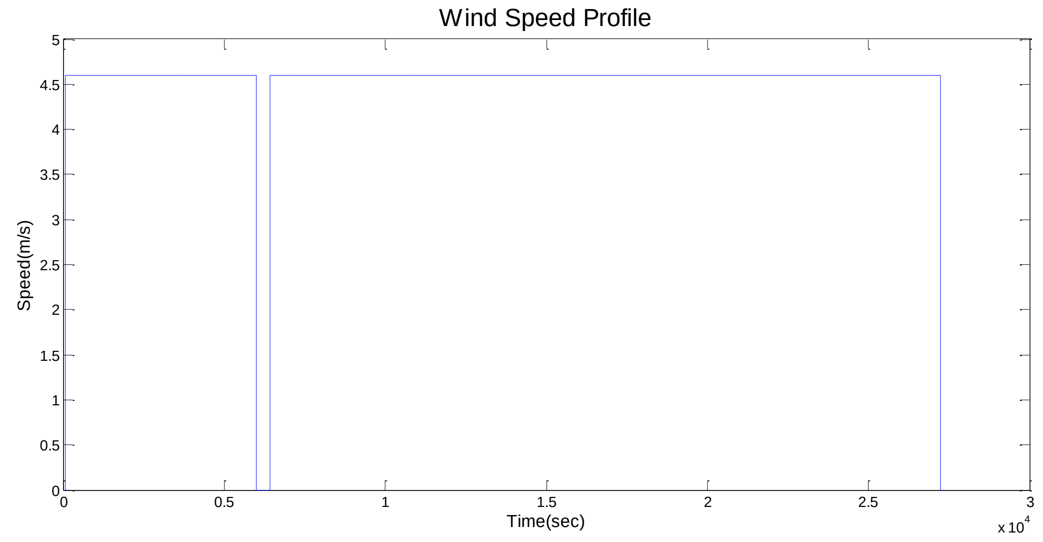
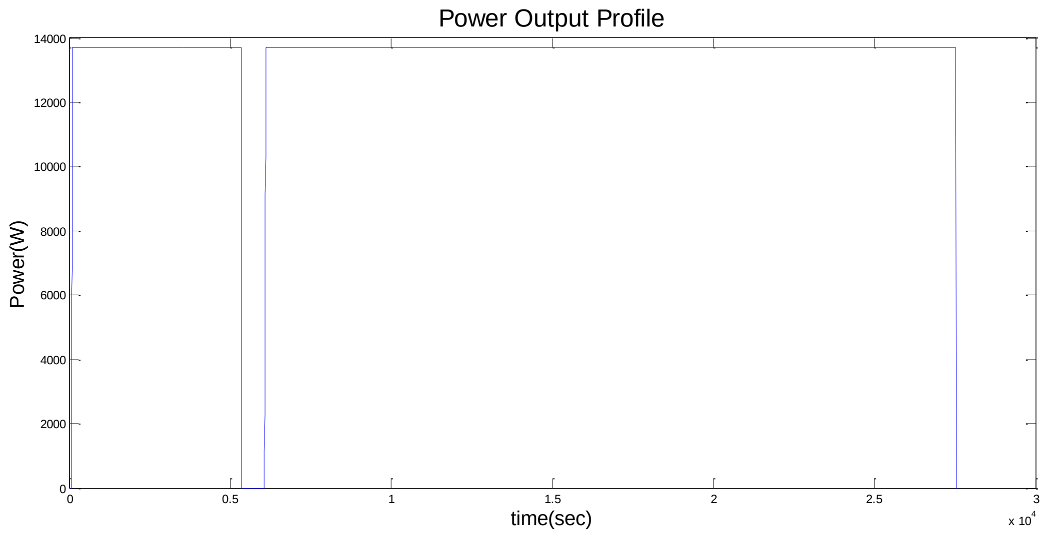


Fig 6. 2 wind speed profile for actual passenger speed



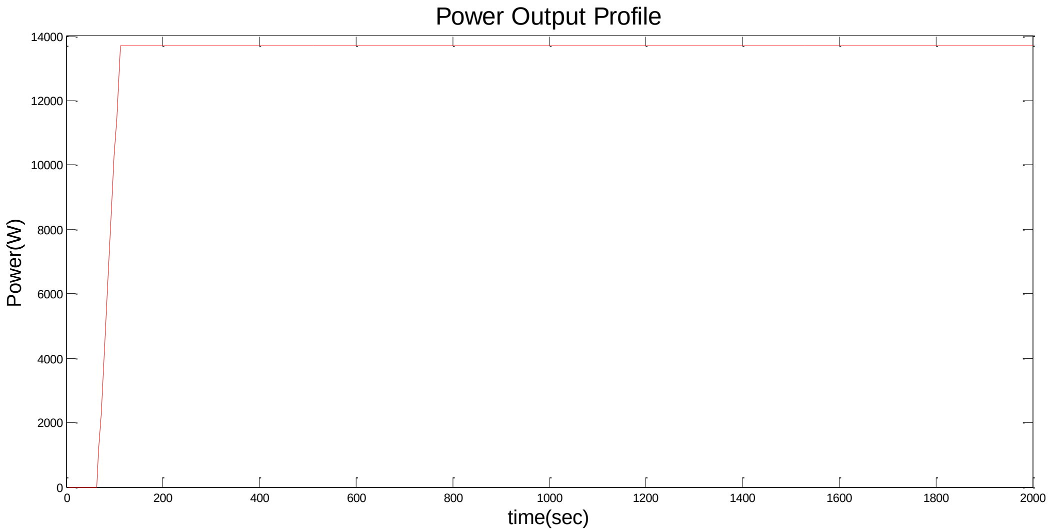


Fig 6. 3 Output power profile for actual fright speed

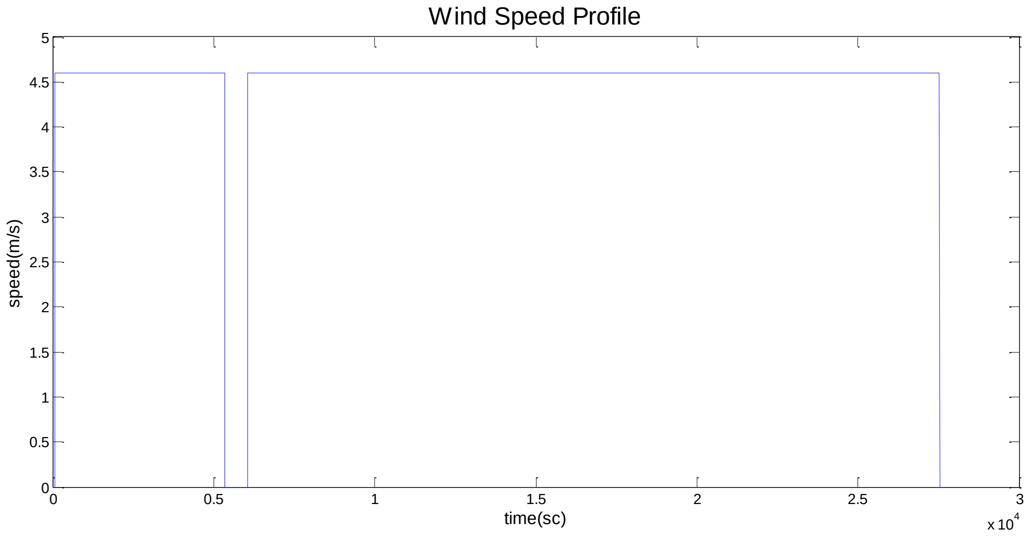


Fig 6. 4 wind speed profile for actual fright speed

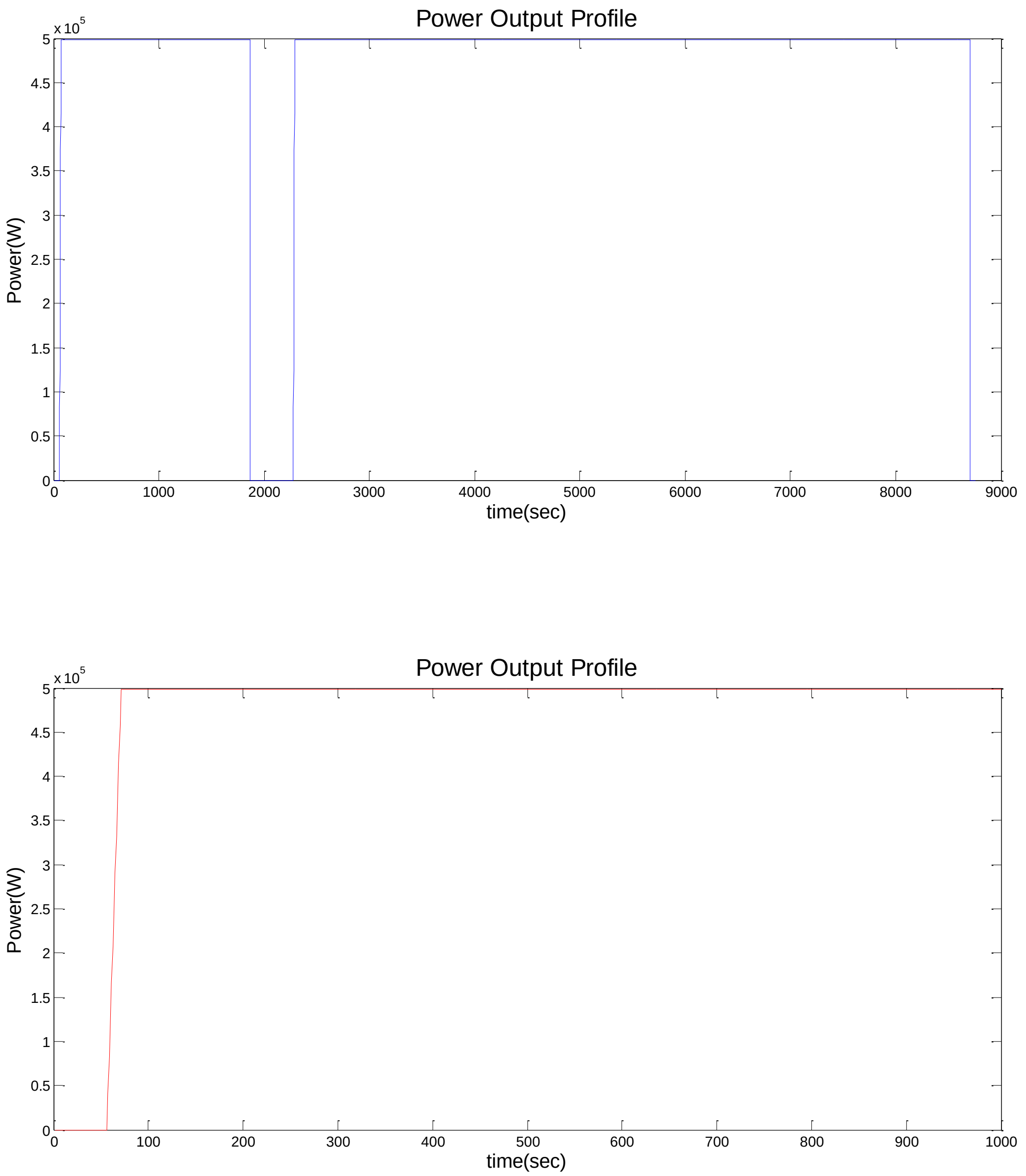


Fig 6. 5 Output power profile for model passenger speed

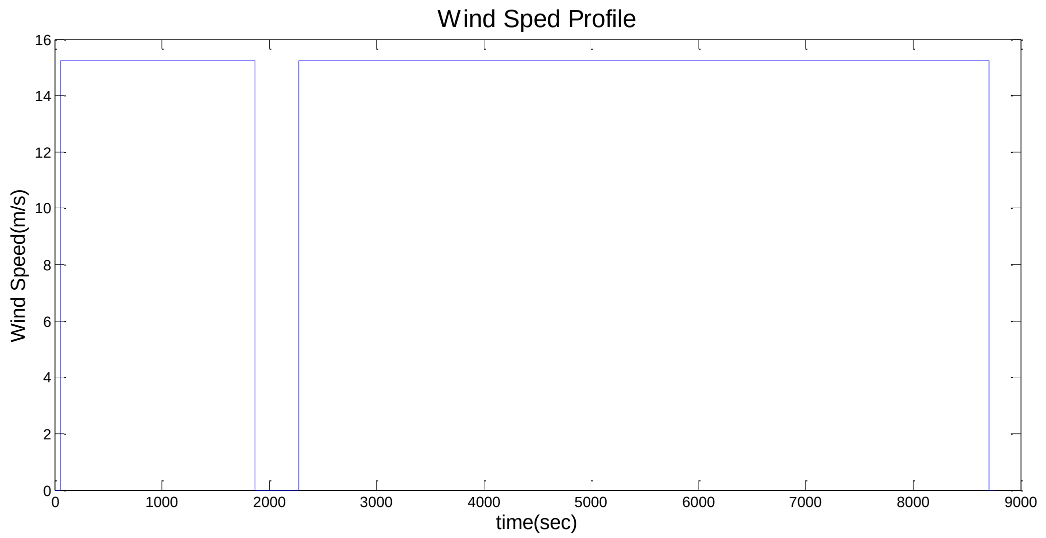
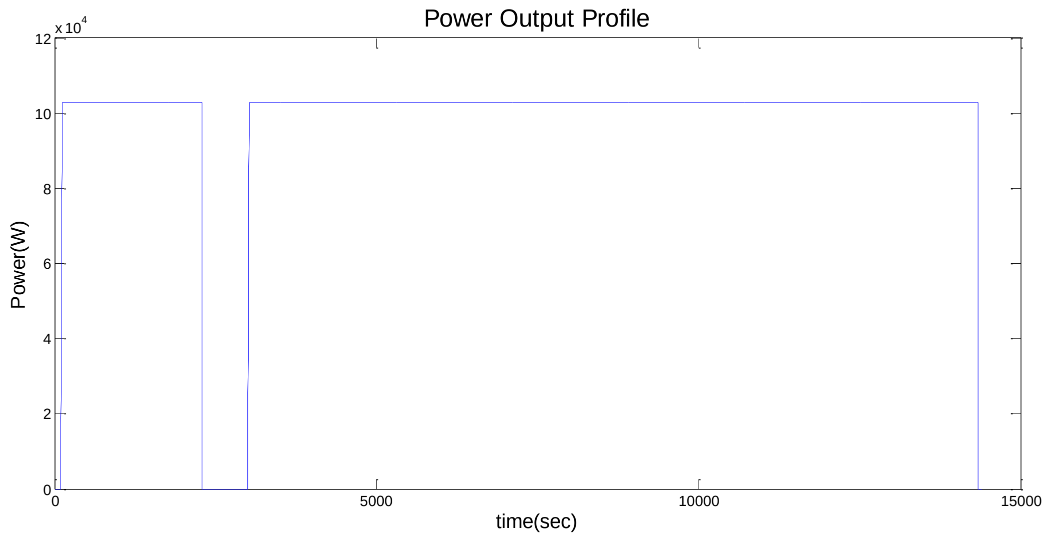


Fig 6. 6 wind speed profile for model passenger speed



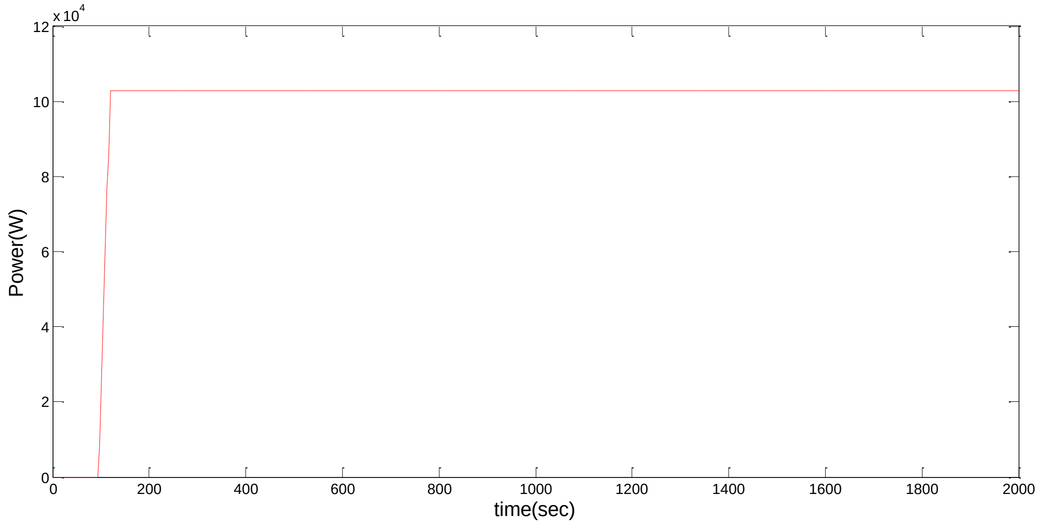


Fig 6. 7 Output power profile for model fright speed

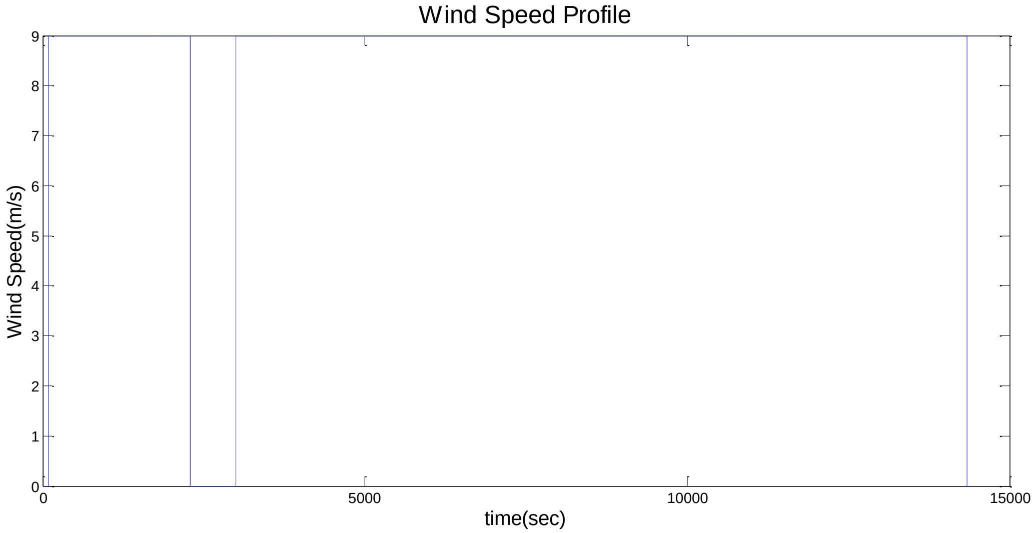


Fig 6. 8 wind speed profile for model fright speed

6.2 Wind turbine output power

The output power from a single turbine is 408W and 84W for fast and slow route respectively, when the train start to move the power output is zero because there is no any turbine installed around until the train is fully accelerated, after that it will rotate 100 turbines per 1.25s and 2.1 s for passenger and freight train respectively. Once it will start to rotate 1200 turbines the power output is constant until stop.

6.3 Economical and Environmental Profit

The profit from the proposed model might be considered from several prospective:

- Saving money
- Fuel economy;
- Carbon dioxide emission reduction;

➢ The existing electric power generation costs are about $0.09 per kilowatt-hour(kWh) [12]

➢ The average cost of diesel in the Ethiopia is 18 birr/liter [13].

➢ Carbon dioxide emission: 1 litter of diesel = 2.68 kg of CO2 [14];

➢ Electrical power to amount of fuel equivalency: 10.7 kWh = 1litter of diesel

The economical profit is calculated based on

- The existing cost of kWh in Ethiopia and
- Electrical power to amount of fuel equivalency

The output power is 1224 kWh per one trip (per day) by the passenger train and 446760 kWh per year. As mentioned above cost of electricity in Ethiopia is $0.09 per kilowatt-hour (kWh) so Savings for a year would be $40,208per year

The output power from freight train is 404 kWh per day and 147460 kWh per year .the saving would be $13271 peryear.

Total =$53,479

One liter diesel oil contains 10.1 kWh (36.3MJ) of energy. A commercial diesel engine has efficiency from 25% to 32%. So energy that can be produced by 1 liter of diesel with 30% efficient diesel engine is: 10.1 kWh × 0.3 = 3 kWh

Energy produced by the passenger train is 1224 kWh per one trip (per day) .Hence, fuel saved by each trip 1224/3 = 408 liter. The average cost of diesel in the Ethiopia is 18 birr/liter. Money saved in one day per train =408×18 = 7344 birr. Savings for a year would be 7344×365 = 2680560($89,352) birr per year.

Energy produced by freight train is 404 kWh per one trip (per day) .Hence, fuel saved by each trip 404/3 = 135 liter. The average cost of diesel in the Ethiopia is 18 birr/liter. Money saved in one day per train =135×18= 2430birr. Savings for a year would be 2430×365 = 886950($29,565) birr per year.

TOTAL =6606litter=$118917 per year

Carbon dioxide emission decrease 17705 kg of CO2 per year

Table 6. 1 investment cost

	Item	Specification	$	Quantity	Total $
1	Turbine	Helical high quality 1000w	190 (20 set) [15]	674480	6,407560
2	generator	12V dc generator low rpm	2	674480	1,348,960
3	Shaft		1	674480	674,480
4	Constriction +manpower				50,000
	Total				**84,653,35**

This will recover the amount spent for setting up the wind turbine arrangement on the railway track in around 71 years. It seems it's not profitable for the current situation of Ethiopia but in the future assuming the trains are operating at high speed and the route runes more than one train per day. For example if 18 trains are passed by the route per day it will recover the cost in short years.

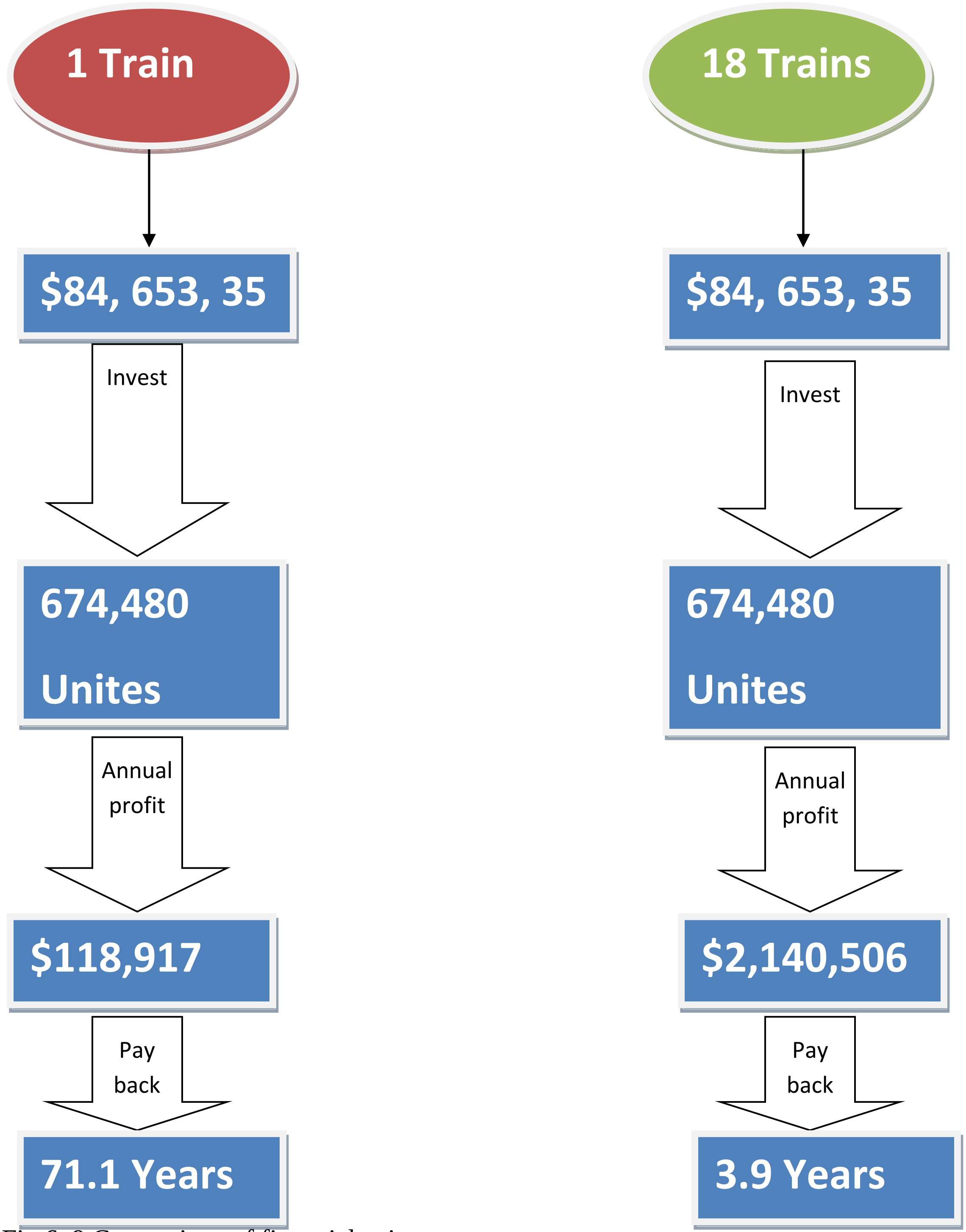


Fig 6. 9 Comparison of financial gain

Figure 6.9 a and b demonstrate the payback period for different scenario. The notable fact is that the cash back time is quite reasonable for the second case the investment made will be recovered in less than 4 years. This numbers are promising and enthusiastic for renewable energy project.

CHAPTER 7 CONCLUSIONS AND FUTURE WORK

This study attempted to generate power by harnessing the wind energy created by fast moving train. The overall power generation capability of the wind energy unit was estimated both mathematically and through simulation, mathematical design of the wind turbine and generator. Afterwards collection of power generated by wind turbine is conducted .Finally, the ecological and economical assets that might be gained in the result of realization of the project were calculated.

In the setup of those large wind turbines we need to invest so much of money. also, they need a large area for it because in wind farms they should be in large in numbers, they are variable and totally depends upon winds and that's why they can't produce continuous electricity. Another important benefit is related to reduction of greenhouse gas emission and fuel economy. The approximation of necessary investment and the payback period has also given positive feedback of the proposed renewable energy unit.

Furthermore, the ideas of sensor and servo motor on the unit, which will be used during the turbines, are not operate, likely to prevent the damage of turbine due to rain, dusts and mechanical hazards and further study on the collection and control of power is quite promising.

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Appendix

```
%for actual passenger train
close all
clear all;
clc

[num,txt,raw] = xlsread('ACTUALPASSENGER.csv');

time=num(:,1);
V=num(:,2);
unites=num(:,3);

A=2*r*l;
for i=1:6825
power(i)= 0.5 * d * A * Cp * V(i).^3 * Ng .*unites(i);
end

power=mean(power)
disp(power)
plot(time,V)
```

```
%for model passenger train

close all

clear all;

clc


[num,txt,raw] = xlsread('MODELPASSENGER.csv');


time=num(:,1);

V=num(:,2);

unites=num(:,3);


A=2*r*l;

for i=1:7008

power(i)= 0.5 * d * A * Cp * V(i).^3 * Ng .*unites(i);

end


power=mean(power)

disp(power)

plot(time,V)
```

%for model freight train

```
close all

clear all;

clc


[num,txt,raw] = xlsread('MODELFRIGHT.csv');


time=num(:,1);

V=num(:,2);

unites=num(:,3);


A=2*r*l;

for i=1:6858

power(i)= 0.5 * d * A * Cp * V(i).^3 * Ng .*unites(i);

end


power=mean(power)

disp(power)

plot(time,V)
```

```
%for actual freight train
close all
clear all;
clc

[num,txt,raw] = xlsread('ACTUALFRIGHT.csv');

time=num(:,1);
V=num(:,2);
unites=num(:,3);

A=2*r*l;
for i=1:6900
power(i)= 0.5 * d * A * Cp * V(i).^3 * Ng .*unites(i);
end

power=mean(power)
disp(power)
plot(time,V)
```