PERFORMANCE ANALYSIS AND RANGE EXTENSION OF E-BIKE AND E-RICKSHAW FOR INDIAN ROAD CONDITION.

THESIS SUBMITTED IN PARTIAL FULFILMENTS OF THE REQUIREMENT FOR THE
DEGREE OF MASTER OF ENGINEERING IN AUTOMOBILE ENGINEERING UNDER FACULTY OF ENGINEERING AND TECHNOLOGY

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DECLARATION OF ORIGINALITY AND COMPLIANCE OF ACADEMIC ETHICS

I hereby declare that the thesis entitled "**PERFORMANCE ANALYSIS AND RANGE EXTENSION OF E-BIKE AND E-RICKSHAW FOR INDIAN ROAD CONDITION.**"Contains literature survey an original research work by the undersigned candidate, as a part of MASTER OF ENGINEERING IN AUTOMOBILE ENGINEERING studies during academic session 2020-2022.All information in this document have been obtained and presented in accordance with the academic rules and ethical conduct. I also declare that, as required by these rules of conduct, I have fully cited and referenced all the material and results that are not original to this work.

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CERTIFICATE OF RECOMMENDATION.

This is to certify that the thesis entitled " **PERFORMANCE ANALYSIS AND RANGE EXTENSION OF E-BIKE AND E-RICKSHAW FOR INDIAN ROAD CONDITION.**" is a bona-fide work carried out by **BIKU KUMAR SINGH** under our supervision and guidance in partial fulfillment of the requirements for awarding the degree of Master of Engineering in Automobile Engineering under Department of Mechanical Engineering, Jadavpur University during the academic session 2020-2022.

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CONTENTS

NOMENCLATURE AND SUBSCRIPTS:

EV= Electric Vehicle.

REEV = Range Extended Electric Vehicle.

RE = Range Extender.

V_s = Velocity of Vehicle.

C_d = Drag Coefficient.

A_f = Frontal Area.

ρ = Density of Atmospheric Air.

M = Gross Weight of battery.

m = Mass of vehicle.

g = Gravitational acceleration.

μ = Coefficient of friction.

a = Acceleration of the vehicle.

F_d = Drag Force.

Fr = Rolling Force.

F_a = Acceleration Force.

F_g = Gradient Force.

F_t = Traction Force.

P_d = Drag Force.

Pr = Rolling Power.

P_a = Acceleration Power.

SOC = State Of Charge.

ICE = Internal Combustion Engine.

Ah = Capacity Of battery.

V = Voltage of battery.

I_b = Current of Battery.

E_t = Traction Energy.

E_b = Battery Energy.

t = Time.

T = Torque .

P_g = Gradient Power.

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Chapter 1

1.1 INTRODUCTION:

Due to the increasing rate of global warming and climate change, whole world decided to reduce the emission of harmful gases release from different sectors. Transportation sector contribute almost 30 to 35% of the total global CO2. Most of the vehicles that we use in our daily life runs on internal combustion (IC) Engines which uses the Fuels like gasoline, diesel etc. and also releases the harmful gases (CO, NOX, CO2 etc).The amount of fossil fuel are limited and these are diminishing in alarming rate and also the extraction of the remaining fossil fuel is very difficult. So the above mention concerns the enough to motivate us to transform the IC Engines into the Electrical Vehicles (EV).

Electric Vehicles (EV) are eco-friendly and they do not releases any harmful gases in running. Also they have less reciprocating and moving part so, the vibration is also lesser than the IC engines and they do not produce any sound pollution. In IC Engine the moving part is Crank and piston but in EV the moving part is Motor. In IC there is petrol tank but in EV there is Battery. There are many types of Electric Vehicles as 1.Hybrid Electric Vehicle (HEV) 2.Plug-in Hybrid Electric Vehicle (PHEV) 3.Battery Electric Vehicle (BEV) also called All Electric Vehicle (AEV) etc.

India is the fourth largest Automobile Sector in the world and India is a great importer of fossil fuel and due to the limited amount of fossil fuel the price of petrol and diesel is increasing day by day. Air quality index of many big cities is very poor due to the harmful emission of gases from automobile and industry. In every year the ranking of India is always on top in the most polluted city in the world so our Government decided to reduce the emission of these harmful gases. We cannot shut down the industries but we can transform the IC engines to the electric vehicle. Our government has announced that the 70 % of the IC engine will be converted into EV by 2030.

But this is not an easy task for the country like India because India is the 2nd largest populated country in the world after China and 60 to 70% of the population lives in rural area SO, installing the charging point like the petrol pump all over the country in this stipulated time is not an easy task. Because EVs have a far shorter driving range than ICE vehicles, range anxiety is the most serious issue that EV owners face. Range Anxiety results from the current's low energy density of the batteries which is 0.565 MJ/kg[2] for Li-ion battery and 43.448MJ/kg[3] for fossil fuel. Enhancing by adding extra batteries, EVs' driving range will be negatively impacted. More electric motor power will have an impact on its performance, and To move the additional weight, more energy is required. Moreover, lengthy battery charge times and the lack of infrastructure for charging have proven an obstacle, particularly in poorer nations for prospective EV purchasers.

Since then, range-extended electric vehicles (REEVs) have been developed to increase its range. A range extender (RE) is used in the REEV power train system, which is integrated with the electrical drivetrain in series and a solenoid to charge the battery [4]. As a result, the REEV will run without a tail pipe in pure EV mode for a set distance. And when the battery is depleted by 70 or 80 % then the RE will start to recharge the battery. we can also charge the battery from the starting of the vehicle when the SOC of the vehicle is 100%. In this case the battery is charged from one side and it is discharge from another side.

The size of components, such as the battery capacity, battery weight, battery cost and charging power of the RE, can be customized with the REEV power train. Long pure EV range with a large battery capacity potentially lowers the total emission from tailpipes. But with having EVs with larger batteries tend to be heavier (high energy).increased production costs and higher consumption. As opposed to that, RE should have sufficient output power for charging to prolong the driving distance of the REEV to a specific target under various driving circumstances.

Chapter -2

2.1 LITERATURE REVIEW.

In this section of literature review some important studies of Range extension of electric vehicle by various method of range extender has done, which make basis of this thesis paper are presented and discussed in a brief manner.

Chiong Meng Soon et al[1] has done their studies and concluded that the limited energy density of batteries has been an issue for electric vehicles, which contributes to drivers' range anxiety. A range extender (RE) is seen as possible answer to this issue. This paper offers a parametric analysis of how component sizing (RE power) affects performance on the range-extended electric vehicle, including battery capacity (REEV),battery cost, range extender power . The study is mainly done for Drive cycle on highways (HWFET) and in cities (MUDC) the study took place.

S. Marker et al[5] has suggested that driver behavior has a substantial impact on the energy usage of electrified vehicles. The study states that the battery sizing is the most important component in EV. It would be more efficient to use a REEV with a smaller battery instead of a BEV with a large capacity battery. They also mention that at a given range of 50 km the BEV covers 50% of the kilometers (corresponding to 90% of all daily distances) while the REEV covers 100% of all daily distances, out of it 70% on electric driving. This leads to less CO_2 emission compared to the combined use of BEV and conventional cars.

João Ribau et al[6]concluded that the energy consumption of REEV will decrease as compared to the ICE vehicle if the majority of the driven distance are for urban commuting. They also compared the energy efficiency and CO_2 emission of four different type of range extender.

Manh-Kien Tran et al[7] provided a descriptive review of different types of EV range extender technologies, which including the internal combustion engines, free-piston linear generators, fuel cells, micro gas turbines, and zinc-air batteries, outlining their definitions, working mechanisms, and some recent developments of each range extending technology. They also compared the different technologies, highlighting the advantages and disadvantages of each, is also presented to help address future research needs.

S Devi Vidhya[8] presented the modeling, design and power management of a hybrid energy storage system for a three wheeled light electric vehicle under Indian driving conditions(IDC). The hybrid energy storage system described in this paper is characterized by effective coupling of Li-ion battery (primary energy source) and ultra capacitor (auxiliary source) interfaced with an efficient bi-directional converter. A design methodology related to vehicle modeling, choice of motor rating, converter design, sizing of Li-ion battery and ultra capacitor pack for the Indian driving cycle are presented.

Shashank Singh[10] Studied To support the legalization of e-rickshaws in the state, it examines their socioeconomic effects and technical features. In an effort to make these cars safer and more effective, the report also makes policy proposals. The In Delhi, the number of battery-powered e-rickshaws has increased from 4,000 in 2010 to more than1,00,000 in 2014 and is currently a crucial component of the state's transportation ecosystem. With the right regulatory environment in place, this method of transportation can increase revenue government generation, urban planning, and assistance with enhancing the transportation system.

Navaneeth M et al[11] When compared to ICE vehicles, Electric Vehicles have had a few significant drawbacks since the beginning of the 19th century, such as shorter lengthier refuelling times, a higher sticker price, and less range. Different battery chemistries have been utilized since the start of the nineteenth century. This essay offers an overview of the main battery types used in electric vehicles and displays the benefits of Solid-State Compared to other battery chemistries, batteries offer notably the liquid-filled Lithium-Ion Batteries. The best battery in drive cycles in India was discovered and a regular ICE bike was converted to an E-bike in this study. Several factors, including energy density, , safety, price, cycle life, etc. has compared .He highlighted why Lithium based SSBs are potential for utilization in EV applications.

V L Kokate et al[13] presented E-rickshaw's past, present, and future. A significant mode of transportation that significantly increases the use of public transportation is the rickshaw. In response to the demand for a motorized mode of transportation, the rickshaw developed with time. From hand-pulled, it has developed. Rickshaw to an e-rickshaw, an electric rickshaw. Being affordable and environmentally friendly means of transportation today when pollution levels are unacceptably high and urbanization. E-rickshaws are steadily gaining popularity in various Indian cities. It is the best alternative for a cost-effective mode of transportation. Still, the e-car market less than 1% of the market. Additionally, it has developed into a highly In the years to come, reliable form of communication and has established itself as a viable career option for those living in rural India or those living in cities who fall into the low-income category. Petrol and diesel are outdated; electric rickshaws are the future.

Deepanjan Majumdar et al[14] has explained about E-rickshaws, or battery-powered electric three-wheelers, have lately entered India's public road transportation market. Due to the convenient and affordable transportation they offer to other commuters, these vehicles have become very popular. The current study is based on a case study in the state of West Bengal, where the journey these vehicles' patterns have been researched. The e-rickshaws' average specific energy usage has been recorded and it was discovered to be 53.76 kJ/passenger-km, making it the most effective type of powered three-wheeled vehicle, cabs for people. This paper also delineates the problems that lie in the way of proper implementation of these In the field of public transportation, e-rickshaws.

2.2 OBJECTIVE OF THE PRESENT WORK:

It is quite evident from the available literature that a considerable amount of experiment and work has been done on range extension of electric vehicle using the micro gas turbine. Many researchers have tried and found many ways to extend the range of electric vehicle.

We found that a considerable amount of research is required to properly understand the effect of micro gas turbine as the range extender in electric vehicle for charging the battery in running phase of electric vehicle.

The following objectives are fulfilled and presented in this thesis:

1. The Traction Force required to drive the E-bike and E-rickshaw.
2. The Traction Power required to drive the E-bike and E-rickshaw,
3. Consumption of energy required per Km.
4. The charging and discharging trend of Li-ion and lead acid battery.
5. How much distance can we travel in how much battery energy?
6. Range extension of electric vehicle by using the Auxiliary power unit.
7. How much range extended in how much power of Auxiliary power?

Chapter -3

3.1 VEHICLE DYNAMICS:

In this chapter we will look that when a vehicle drives then what is the force required to run the vehicle? What is the power required? What is the peak power it is required? What is torque required? What is the speed at which you are moving and Most importantly how much total energy required to drive the vehicle etc. These are very important aspect because after knowing these all parameter we can use the motor and battery of the required specification for the required range.

The force that required driving the vehicle is the Traction Force. Traction Force is composed of:

1. Drag Force.

2. Rolling Force.

3. Acceleration Force.

4. Incline Force.

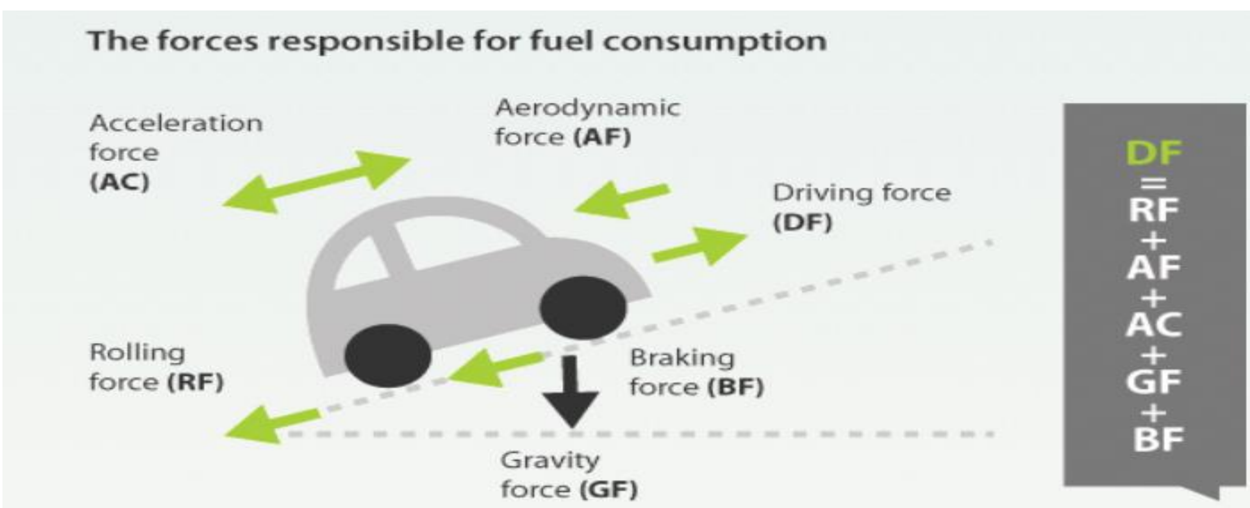

Fig: 1 Forces acting on a vehicle on a incline plane.

These are the forces responsible for the fuel consumption in IC engines and power consumption in EV.

3.1.1Aerodynamic force or Drag force:

Drag Force is the air resistance force which will act opposite to the direction of vehicle in running. We can easily feel this force by putting our hand outside the window in running car. Mathematically Drag is given by:

$F_d = ½*ρ*Cd*A*V^2$ ------------------ (1).

Where,

Fd = Drag Force.

ρ = Density of Atmospheric Air (@ 27°C ρ is equal to 1.27 kg/m3).

C_d = Drag Coefficient.

A_f = Frontal Area (m^2).

V = Velocity of vehicle (m/sec).

So from the above equation we can easily understand that drag force is directly proportional to the square of velocity. So if we increase the velocity by double then the drag force will increase by quadruple.

3.1.2 Rolling Force:

This is the force applied by the road to the tyre of the vehicle .This resistance force is important for the movement of the vehicle but if it increase more than that required then the fuel consumption of the vehicle will increase. Mathematically it is given by:

$F_r = m*g*μ*CosΘ$ ---- ---------------- (2).

Where:

M = gross mass of the vehicle (mass of the vehicle + loading of the vehicle).

g = Acceleration due to gravity (g = 9.81 m/sec^2).

μ = Coefficient of friction (depend on the quality of tire and the condition of road).

CosΘ = Θ will come in the case of inclination of road. if the road is flat then the Θ will be zero and the value of cosΘ will be one.

Also, if the inclination is low then we can take Θ be very small and then the value of cosΘ will be one in this case.

This force is totally depending upon the mass of the vehicle and the gross mass of the vehicle (mass of the vehicle + loading of the vehicle). it is self generating force if the mass of the vehicle will increase then the rolling force will increase.

3.1.3Acceleration Force:

The force which is required to accelerate the vehicle. We all know that mathematically it is given by:

$F_a = m*a$ ---------------------- (3).

Where;

m = Gross mass of the vehicle in kg (mass of the vehicle + loading of the vehicle).

a = Acceleration of the vehicle (m/sec^2).

The value of this force may be positive and negative it's depending upon the velocity of the vehicle. When vehicle decelerate its value decreases and when accelerate its value increases. And as we can see from the equation 3 acceleration force is directly proportion to mass also.

3.1.4 Inclination or Gradient Force:

This force will come in the picture when the road has some slope or inclination. We can observe from the above fig.1 that there is two component of the weight of the vehicle one is parallel and one is perpendicular to the incline road and their value is mg*sinΘ and mg*cosΘ respectively. This force will act opposite to the direction of vehicle in parallel direction. Mathematically it is given as:

$F_g = m*g*\sin\Theta$ ------------------------- (4).

So the total force required to drive the vehicle is the summation of all the forces and this is called the traction force. So Traction force is given as:

$F_t = F_d+F_r+F_a+F_g$ -------------------------- (5) .

We have derived the equation for the total force required to drive the vehicle now we need to find the traction power and peak power required to drive the vehicle and the total energy required to drive the vehicle.

Power is defined as the force multiplied by the velocity and mathematically it is given as:

$P_t = F_t*V$ -------------------------- (6).

Where;

P_t = Traction Power (Kw).

F_t = Traction Force (N).

V = Velocity of the vehicle (m/sec).

Peak power is the maximum power required to drive the vehicle. Mainly at the time of inclination or at the time of maximum speed there is required of peak power.

Now we have calculated the power required and peak power required now we need to find the total energy required to drive the vehicle .We can easily calculate it by integrating the power with the time and it is given by:

$$E_t = \int_{t1}^{t2} \mathrm{Pt} * dt \qquad \text{---------------------------- (7).}$$

Torque required to derive the vehicle can also be calculate if we know the radius of the wheel of the vehicle and it is given by:

$$T = F_t * R_w \qquad \text{------------------------------ (8)}$$

Now by using the equation 1,2,3,4,5,6,7,8 we can find all the parameter required to drive the vehicle by using these equation we can also calculate the power of motor required and its specification ,consumption of the vehicle per km and also the range of the vehicle .

In this paper we will look for the force, power, energy, range etc for two wheeler and e-rickshaw. And all the calculation is done in MATLAB programming.

Specification of Two Wheeler.

Mass of the vehicle (m) = (mass of vehicle + mass of loading)

= (100kg+80kg.)

Projected /Frontal Area (A) = 0.5 m^2

Density of atm. Air @ 27˚C (ρ) = 1.2 kg/m^3

Coefficient of Drag (Cd) = 0.9.

Acceleration due to gravity (g) = 9.81 m/sec^2

Slope (ϴ) = 5˚

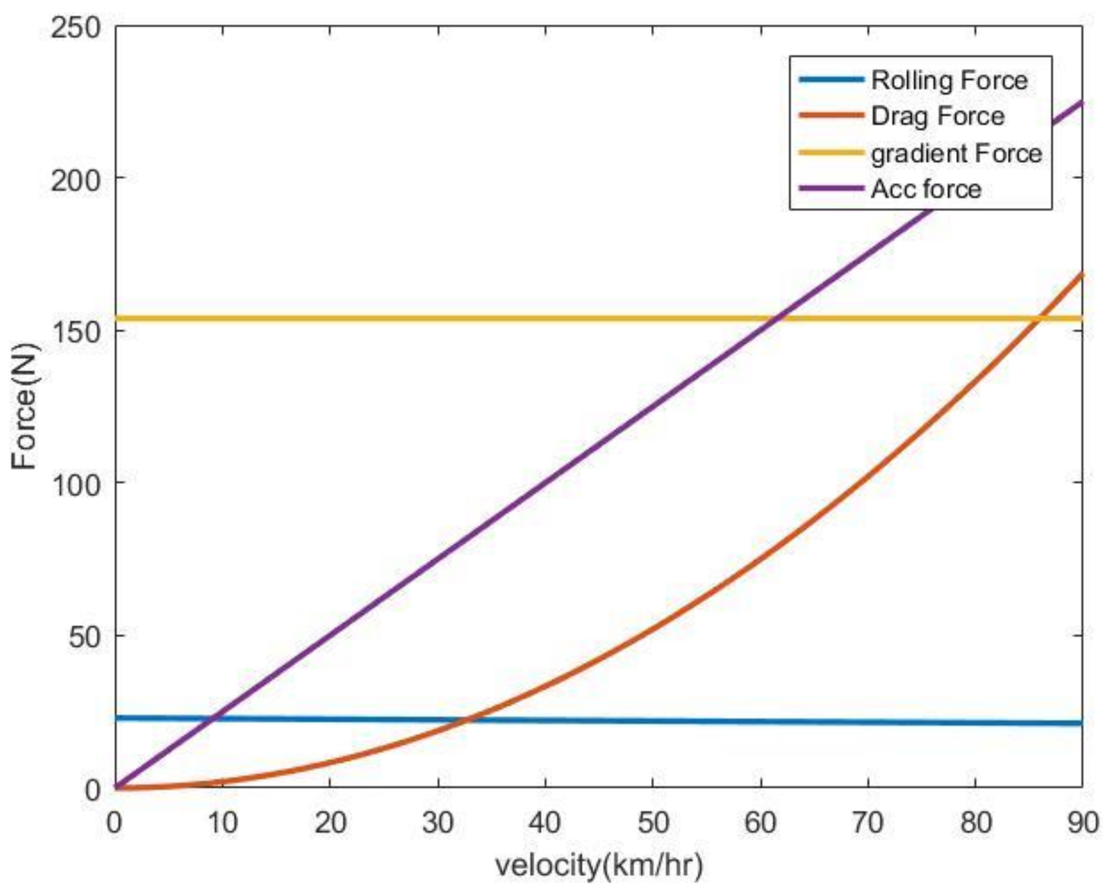

Fig: 2 Graph between the velocities of vehicle in km/hr versus the different forces in Newton.

There are four curves in the above plot for four different forces at different speed i.e. drag force, Rolling Force, Gradient Force and Acceleration force.

We can easily observe from the above graph that rolling force is almost constant because it does not much depend upon the velocity of the vehicle .it depends upon the mass of the vehicle and the rolling coefficient and the rolling coefficient is almost same for kinetic and static situation .There is a only a slight difference in rolling coefficient so this force is almost constant for every speed of the vehicle.

The force due to rolling resistance on a reasonable tarmac road is actually small. We can easily observe from the above graph at the start it is only 25 N and when the velocity increases the static friction change to kinetic friction so it decrease to some 23 N to 24N So, we can say that rolling resistance for two wheeler would be maximum 30N or 35N in case of the loading of the vehicle. So this is not a major force.

Now we will look for drag force so at the start of the vehicle the influence of the drag force is low because drag force depends on the velocity and the velocity at the start of the vehicle is low. And it does not depend on the mass of the vehicle. And it is directly proportional to the square of the velocity so the curve of the drag force is the square of the velocity curve. At start of the vehicle it is low and even lower than the rolling force but as the velocity increase it increases rapidly. Up to the 50-60km/hr the value of drag force is low we can observe from the graph. At 60 km/hr the value of drag may be 60 or 70 N and this is not a major force. But as it goes to higher velocity like 80km/hr to 90km/hr the force required due to drag increase significantly.

Now the other curve is of inclination or gradient force and we can observe from the graph that even at 5 degree slop their value is very high. it is also the constant force because it does not depend upon the velocity it only depend upon the mass and the slope .This will come in the case of incline road this value is zero in the case of flat road .and also in the case of inclination the velocity of vehicle is low so the value of drag force is also low and rolling force is already lower so in case of incline road we need to worry about the gradient force for two wheeler their value is 150N TO 160N at any speed.

Now the major force is the acceleration force and this will also depend on the velocity of the vehicle. So when we want to achieve the maximum speed at less time than the force would be more. in the above fig 1. it has been taken 20 sec to reach the particular velocity

So we can easily observe the different value of forces at different speed but at constant acceleration the force would be same but it has some value. At higher inclination we don't accelerate the vehicle so the value of acceleration force would be low and the gradient force will dominate .and when the slope is zero then we accelerate the vehicle then the gradient force will be less. So these two forces will comes with some condition, but the drag force and rolling force will always present.

From the above graph we can easily calculate the value of traction force at any velocity of the vehicle.

Table: 1.Traction Force of two-wheeler vehicle with gradient/slope 5°

Sr. No	**Velocity (Km/hr)**	**Drag Force(N)**	**Rolling Force(N)**	**Gradient Force(N)**	**Acceleration Force(N)**	**Traction Force(N)**
1	10	1.6875	22.779	153.9	22.5	200.87
2	30	17.521	22.387	153.9	72.5	266.31
3	50	50.021	22.808	153.9	122.5	349.23
4	70	99.188	22.809	153.9	182.5	458.4
5	90	165.02	22.809	153.9	222.5	564.23

Table: 2.Traction Force of two-wheeler when slope is 0° or flat road.

Sr. No	**Velocity (km/hrs)**	**Drag Force(N)**	**Rolling Force(N)**	**Acceleration Force(N)**	**Traction Force(N)**
1.	10	1.6875	22.7788	22.500	46.9663
2.	30	17.5208	22.3866	72.500	112.4047
3.	50	50.0208	22.8080	122.500	195.3288
4.	70	99.1875	22.8085	182.500	304.496
5.	90	165.0208	22.8086	222.500	410.3294

From table 1 and 2 we can observe the value of forces which is required to drive the vehicle for both the cases i.e. the incline road and flat road. Now we will look for the power required to drive two wheeler vehicles.

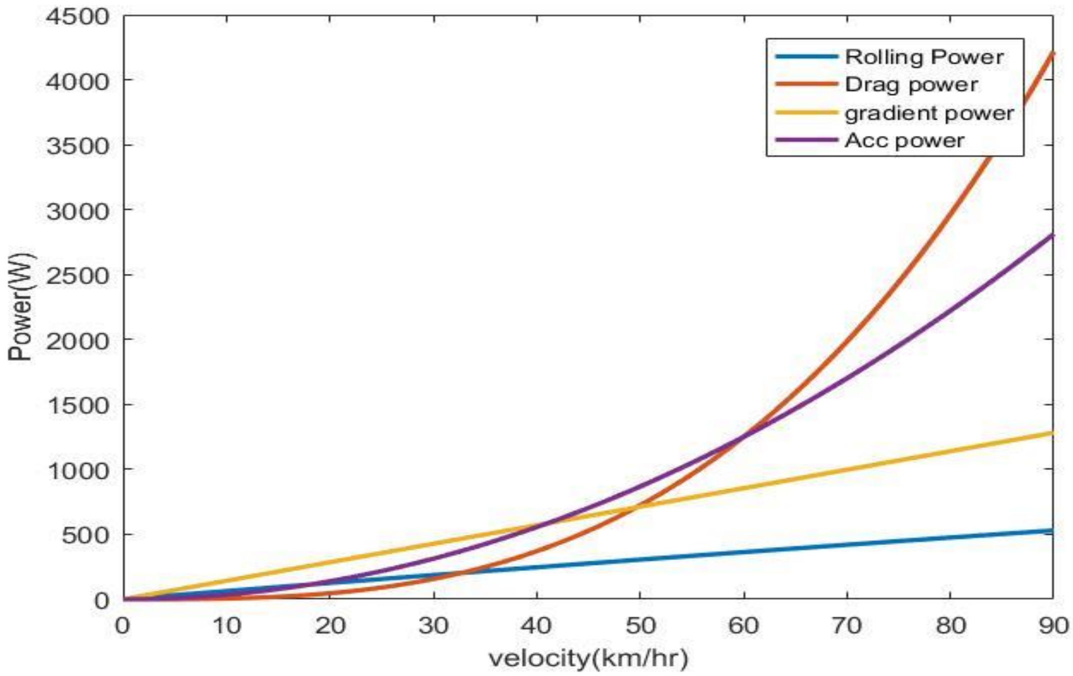

Fig 3. Plot between the velocities (km/hr) of the vehicle versus the power (w) required

There are four different power curve in fig.3 .Power is calculated as force multiplied by the velocity. So all curve is a function of velocity. Either the force is constant or not it does not matter the power would be variable because it is the function of velocity and velocity changes at every point.

Drag power is the function of cube of velocity so at higher velocity the drag power would changes significantly. But till the 50 to 60 km/hr the drag power is less i.e 500W or 0.5kw. But as the speed increase the drag power increases significantly we can observe from the above graph. Whereas the rolling power and the gradient power is low they can reach maximum to 0.5kw and 1.5kw and the gradient power will only present at the incline road not on the flat road.

The two power i.e. Gradient power and acceleration power will not exist together because when there is incline road we cannot accelerate the vehicle .we can go only for 15 to

20km/hr. So in that case we are more focused on gradient power. When the velocity is 60km/hr here it is taken 20km/hr and when the velocity is 90km/hr here it is taken 30km/hr in case of incline road. And when the road is flat then there is no any gradient power only the acceleration power will come .But the drag power and rolling power will always be there whatever the cases.

If we calculate all these power and add them then we can find the power required at different speed and this is the average power required by the vehicle .When we want to achieve the maximum velocity at minimum time then the pickup power is required. This can be possible only on flat road and in this case the acceleration power will dominate .So let us understand the configuration of motor required for all the speed and also for slope road.

Table: 3 Power required by the vehicle on flat road.

Sr. No	**Velocity (Km/hr)**	**Drag Power(W)**	**Rolling Power(W)**	**Acceleration Power(W)**	**Traction Power(W)**
1	10	4.2188	56.9471	28.1250	89.2909
2	30	141.140	180.3351	292.0139	613.489
3	50	680.8391	299.3631	833.6805	1813.8827
4	70	1901.093	414.0311	1653.1250	3968.2491
5	90	4218.750	531.3351	2750.3472	7500.4323

The configuration of motor for two-wheeler bike can be decided by the fig.3 and table3 .When the vehicle speed is 10km/hr to 20km/hr then only 1kw motor is enough to drive the vehicle. We can observe from the table that up to the 40 to 50km/hr speed only 2kw motor is enough to drive the 2-wheeler vehicle. So for the low cost vehicle and low speed vehicle 2kw motor is enough to drive the vehicle. But here the maximum speed limit would be 40 to 50km/hr.

But if we want a e-bike with 80 to 90 km/hr speed then the power of motor should be more. We can easily observe from the graph and table that at 70 and 80km/hr only the drag power is 4kw and when we add the remaining two powers then the power required would be 8kw to 9kw. So to drive the two wheeler bike we need 8kw to 9kw powered motor.

Now if we want to calculate the Range and Power consumption per km then we can simply integrate the power with time and we can find the total energy consumed. When velocity is multiplied by time then we can find the distance travelled in that particular time. So we have the energy consumed in that time and we have the distance travelled in that particular time. Then consumption of the vehicle per km is calculated as the energy dived by the total distance so by this we can calculate the kwh/km of the vehicle[2].

$D = v*t$ -------------------------------------- (9)

Where,

D = distance travelled by the vehicle.

V = velocity of the vehicle.

t = time taken.

$E_{/km} = E_t/D$ -------------------------------------- (10)

$E_{P/km}$ = Consumption of the vehicle per km.

E_t = Total energy consumed.

D = distance travelled in particular time.

All the above data and calculation is on the general basis and this is not the real case. For real case we need the Drive cycle of India. Later on we will define the drive cycle and we will do the calculation for the drive cycle by the help of above equations.

3.1.5 E-Rickshaw

Now E-rickshaw becomes the dominant passenger vehicle in India for local use. 60 to 70% of people live in rural area and in rural area e-rickshaw is the major passenger vehicle and also it is use for goods transportation like to carry the vegetables from village to town. And we all aware that the electricity system in village is not so good so if we find an alternate way to extend the range extension of E-rickshaw then it would be blessing for the people of India. Many people are employed by driving the e-rickshaw they earn Rs 600 to Rs700 daily [10]. The charging time of e-rickshaw is generally 6 to 7 hrs. And mainly it is charged at the night time so due to the more power cut at the night time. They are unable to charge the battery full and they can run their vehicle for less time . So in this paper we will try to increase the range of electric vehicle by alternate method. But for this first of all we need to know about the force required to drive the e-rickshaw, power required to drive, the consumption per km, and what is the range in the single charge etc.

Specification of E-rickshaw:[9][10]

Mass of E-rickshaw (m) = (380kg+300kg.)

Projected /Frontal Area (A) = 1.6 m^2

Density of atm. Air @ 27°C (ρ) = 1.2 kg/m^3

Coefficient of Drag (Cd) = 0.44.

Acceleration due to gravity (g) = 9.81 m/sec^2

Slope (Θ) = 5°

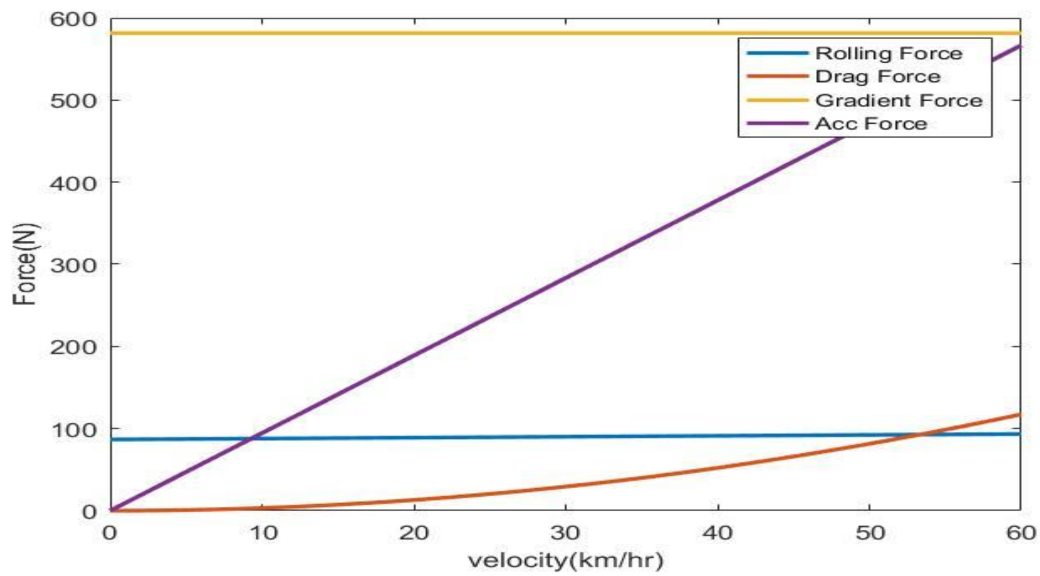

Fig. 4: Graph between the velocities of vehicle in km/hr versus the different forces in Newton. For e-rickshaw.

Here, also there are four different curve like the two wheeler i.e. 1.Drag force 2.Rolling force 3.Gradient Force 4.Acc Force. Now we will understand the variation of force with the speed of the vehicle like what we have done for two- wheeler.

The speed of the E-rickshaw is limited to only 25km/hr by the Gov. of India and also it cannot run on highway and incline road and we can also observe from the graph that the influence of drag force is not so high because drag force totally depend on the square of the velocity of the vehicle and the velocity of the vehicle is limited. So drag force would go to 120 N maximum at 60km/hr although 60km/hr speed is not allowed but we are doing here for our observation .Now we will talk about the rolling force which acts on the tire by the road and it depend on the mass. And rolling force does not depend more upon the velocity of the vehicle. Only there is slight change in the rolling force when the velocity of the vehicle increases and decreases. We can observe from the above graph that the rolling force is almost constant and their influence is also not so high. Their value of rolling force is almost 100N. It is double of two-wheeler but still their influence is not so much.

Now we will observe another two forces i.e. the Gradient force and the Acceleration force. The value of gradient force is high we can observe from the above graph but at the time of inclination the speed of the vehicle is very low and also driving on incline road is not allowed for e-rickshaw SO, we should not so much worry about the gradient force . But when the road is flat we can accelerate the vehicle and at higher velocity the acceleration force is considerable.

Now we will take some speed and we will observe the different force at that speed and also the traction force at that speed.

Table 4: Force required driving e-rickshaw on incline road.

Sr. No	**Velocity Km/hr**	**Drag Force(N)**	**Rolling Force(N)**	**Gradient Force(N)**	**Acceleration Force(N)**	**Traction Force(N)**
1	5	0.5393	87.1727	581.3985	38.4181	707.5286
2	10	2.7302	87.7380	581.3985	86.4407	758.3074
3	15	6.6065	88.3033	581.3985	134.4633	810.7716
4	20	12.1682	88.8686	581.3985	182.4859	864.9212
5	25	19.4151	89.4339	581.3985	230.5085	920.756

Table 5 : Force required to drive e-rickshaw on flat road .

Sr. NO	**Velocity Km/hr**	**Drag Force (N)**	**Rolling Force(N)**	**Acceleration Force(N)**	**Traction Force(N)**
1	5	0.5393	87.1727	38.4181	126.1310
2	10	2.7302	87.7380	86.4407	176.9089
3	15	6.6065	88.3033	134.4633	229.3731
4	20	12.1682	88.8686	182.4859	283.5227
5	25	19.4151	89.4339	230.5085	339.3575

Now we have the traction force for both the condition i.e. the flat road and incline road but we are more interested for the 5th table of flat road. Because E-rickshaw is allowed for the flat road and for limited speed. Maximum traction force is 340 N we can observe from the above so, according to thus data we can assume that the torque required would be low and also the power required would be low. Now we will calculate and draw the graph for the power required to drive the e-rickshaw. Power is calculated as the force multiplied by the velocity. We have already calculated the force at different speed now we can easily calculate the power with the help of above equation.

All the data and equation is computed in MATLAB and all the value of power and force is calculated with the help of MATLAB programming. The graph is also plotted with the help of MATLAB programming. Let us observe the graph and detect the different power at different speed so that we can know about the configuration of motor required to drive the e-rickshaw.

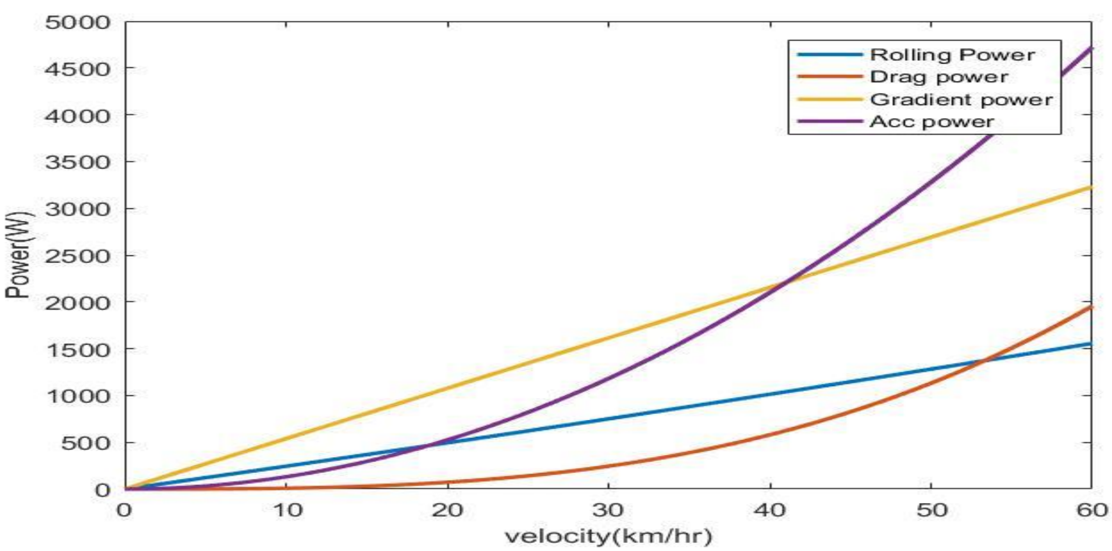

Fig.5: plot between velocity (km/hr) and Power (W) of e-rickshaw.

From the above graph we can easily observe that what is the power required to drive the e-rickshaw at different velocity. Let us first understand the behavior of the entire four curve, how they are changing with the velocity etc. We have already defined the power that power is force multiplied by the velocity so all these curve is the function of velocity.

Drag power is the function of cube of velocity but its effects till the 25km/hr is not too high as we can observe from the above graph but as we go beyond the 30km/hr speed, value of drag power changes significantly.

Effect of rolling power is also not high till the 25km/hr. we can observe from the above graph. But it is always present from starting of the vehicle to the running of the vehicle. Rolling power is function of velocity only so as the speed increases so the power will also changes linearly.

Now, the remaining two powers will not present at the same time because at the time of inclination we cannot accelerate the vehicle so at that time we will more concern about the gradient power. And that gradient power is enough to drive the vehicle. We need not required to take the acceleration power. But we have already discussed that the e-rickshaw is not allowed to drive at incline road so we are more interested to find the acceleration power. Now we will take the data of the traction power at different speed from the above graph.

Table 6: Power required driving e-rickshaw on flat road.

Sr. No.	**Velocity (km/hr)**	**Drag Power (Watt)**	**Rolling Power (Watt)**	**Acceleration Power(Watt)**	**Traction Power(Watt)**
1	5	0.6094	58.5002	21.7051	80.8147
2	10	6.9413	223.0627	109.8822	339.8862
3	15	26.1275	349.2221	265.8878	641.2374
4	20	65.3093	476.9785	489.7220	1032.0098
5	25	131.6279	606.3318	781.3847	1519.3444

From the above table we can observe that the power required at 25km/hr is 1.5kw and at 30 km/hr it may be 2.5kw and at 15km/hr it is 1kw So, to drive the e-rickshaw we required a motor of 2.5 kw.

Now we need to calculate the consumption per km of energy. So we can calculate the power of battery. If we know the consumption per km then we can also know that for any range how much power battery is required.

The above calculated data and graph is the general case. In reality the speed of the vehicle does not change like this. In actual case the vehicle may accelerate and decelerate according to the condition of traffic and situation. So, how we can know the real speed, force required, power and energy required. We can know the real velocity and all by the drive cycle. So let us talk about the drive cycle of India for two-wheeler and e-rickshaw.

3.2 Concept of Drive cycle:

Drive cycle is a collection of data representing the speed of the vehicle at different time. Different countries have different drive cycle to access the performance of vehicles in different ways like the fuel consumption, electric vehicle autonomy, and polluting emission. A drive cycle is a standardized, so that different vehicle can be tested and compared. Each vehicle such as two-wheeler, three-wheeler, car, bus etc has different drive cycle. Each city/town may have its own drive cycle. For climbing up and down generally there is no any drive cycle. Drive cycle defined for a limited time and distance so for any particular time and distance we will repeat that cycle.

3.2.1 Indian drive cycle (IDC) for two-wheeler.

As we are doing our research for Indian road so, Indian derived cycle is taken from automotive research Association of India (ARAI) as shown in the fig: 6

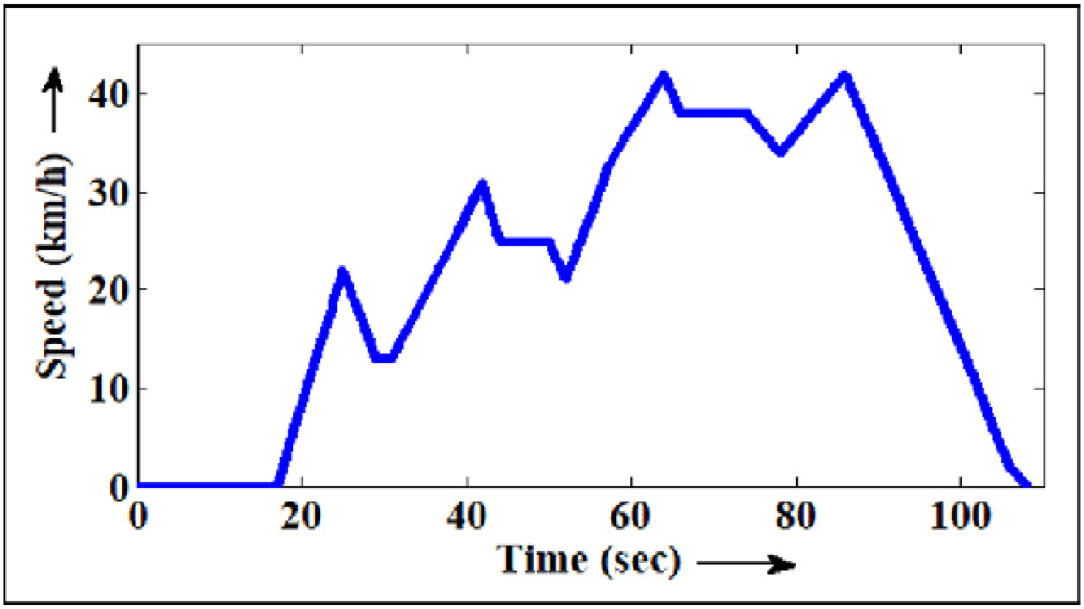

Fig: 6 Indian Drive Cycle.(2W & 3W)

With the help of the above drive cycle, we can calculate the acceleration, deceleration, and steady state of the vehicle.

Table 7: Position of 2W & 3W according to Indian Drive Cycle:

No. of operation	**state**	**speed**	**Duration of each operation(Sec)**	**acceleration (m/sec^2)**	**Cumulative time(Sec)**
1	idling	----	16	---	16
2	Acceleration	0-14	6	0.65	22
3	Acceleration	14-22	4	0.56	26
4	Deceleration	22-13	4	-0.63	30
5	Steady speed	13	2	0	32
6	Acceleration	13-23	5	0.56	37
7	Acceleration	23-31	5	0.44	42
8	Deceleration	31-25	3	-0.56	45

9	Steady speed	25	4	0	49
10	Deceleration	25-21	2	-0.56	51
11	Acceleration	21-34	8	0.45	59
12	Acceleration	34-42	7	0.32	66
13	Deceleration	42-37	3	-0.46	69
14	Steady speed	37	7	0	76
15	Deceleration	37-34	2	-0.42	78
16	Acceleration	34-42	7	0.32	85
17	Deceleration	42-27	9	-0.46	94
18	Deceleration	27-14	7	-0.52	101
19	Deceleration	14-0	7	-0.56	108

From the above table (7). We can conclude that:

Table: 8 Specification of Drive Cycle.

Sr. No.	**Particulars**	**Time(s)**	**Percentage**
1	Idling	16	14.81
2	Steady speed periods	13	12.04
3	Acceleration’s	42	38.89
4	Deceleration’s	37	34.26
		108	100

1. Maximum speed during the drive cycle = 42kmph.
2. Theoretical Distance Covered per cycle = 0.658km.
3. Average speed during the drive cycle = 21.93kmph.

Now, we have the actual speed, acceleration and the time from the Indian drive cycle. So by using the above equation and the table7 we can find the Acceleration force, Rolling

Force and drag force. And by the help of this force and velocity we can find the traction power and from this power and the specific time we can find the actual energy required to drive the e-bike. If we know the energy and the distance travelled in that energy then we can find the range of the vehicle.

Without battery we are taking the mass of vehicle is 105kg. And we are taking the mass of loading is 70kg. And we will take the mass of battery from the below table: 9.

3.2.2 LI-ION BATTERY:

Table 9: Specification of li-ion Cell.

Manufacture	Panasonic
Type	Cylinder
Model	NCR18650B
Length(m)	0.0653
Dia. (m)	0.0185
Mass(kg)	0.048
Capacity(Ah)	3.2
Nominal Voltage(V)	3.7
Over Voltage(V)	4.2
Under Voltage(V)	2.8
C-rate(continuous)	0.9
c-rate(peak)	1.2

For Two-wheeler the battery voltage is 36V, 48V, and 52V. In this project we are taking the 48V. So, we can calculate the no. of cells in series because the voltage of battery is calculated as: No. of cells in series × Nominal voltage of one cell.

No. of cells in Series = 13.

Similarly the no of cells in parallel is calculated as: Capacity of battery ÷ capacity of one cell.

We are taking the capacity of battery as 2500wh.

No. of cells in parallel = 16.

Total no of cells = 208

Table 10: Specification of li-ion battery:

Sr. No.	Parameter	Data
1.	Battery Energy(wh)	2500
2.	Battery Volumetric Energy Density(wh/m^3)	674448.6271
3.	Mass of Battery(kg)	10
4.	Battery Specific Energy Density(wh/kg)	250
5.	Battery Nominal Voltage(V)	48
6.	Battery Over Voltage(V)	54.486
7.	Battery Under Voltage(V)	36.324
8.	Battery Capacity(Ah)	52.08
9.	Battery Current(Amps)	46.872
10.	Battery Current peak(Amps)	62.496
11.	Battery Power(watt)	2249.856
12.	Battery Power peak(watt)	2999.808

Now we have the mass of battery, mass of vehicle, mass of loading so, we can find the gross mass of vehicle M = (10+105+70=185kg).

From the drive cycle we have calculated the velocity, acceleration and deceleration of the vehicle. Now we will put all these values in the above equation from equation 1st to 10th then we will get the all forces and power required to drive the vehicle.

In this thesis paper we are doing all the equation in MATLAB and we are getting the different graph of of forces, power, and the energy required as shown below. And from this graph we can easily understand that what are the forces, power and energy required to drive the e-bike.

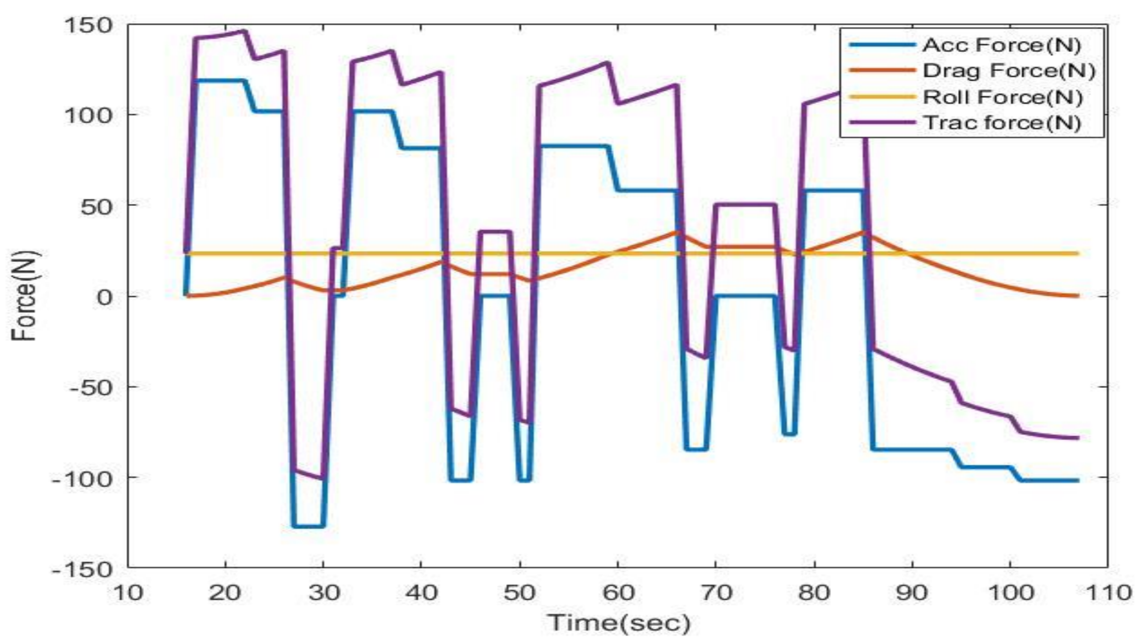

Fig: 7 Graphs Between The Different Forces (N) versus Time (Sec).

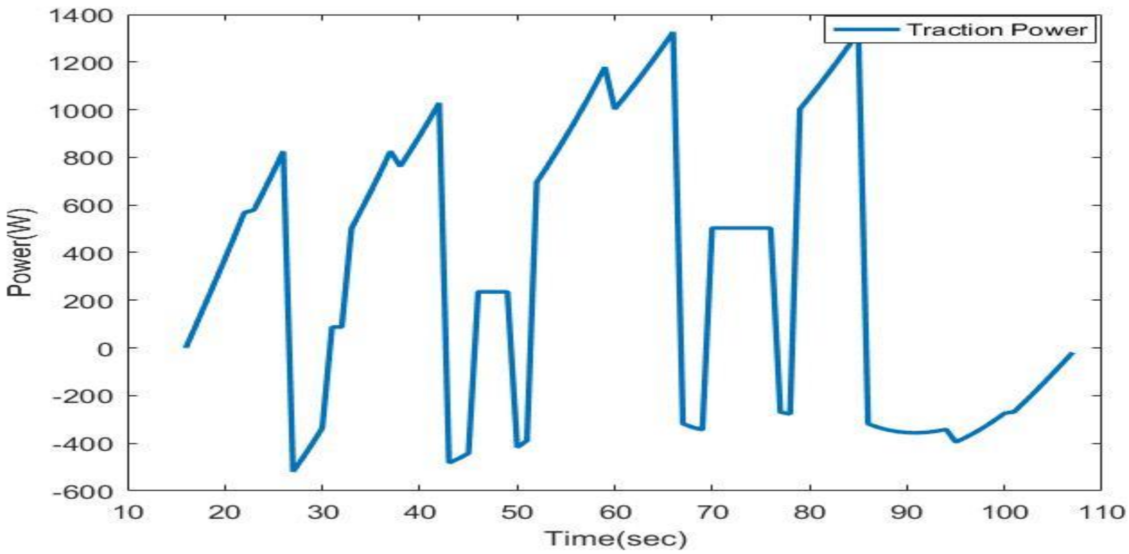

Fig: 8 Graphs Between The Power (Watt) versus Times (Sec).

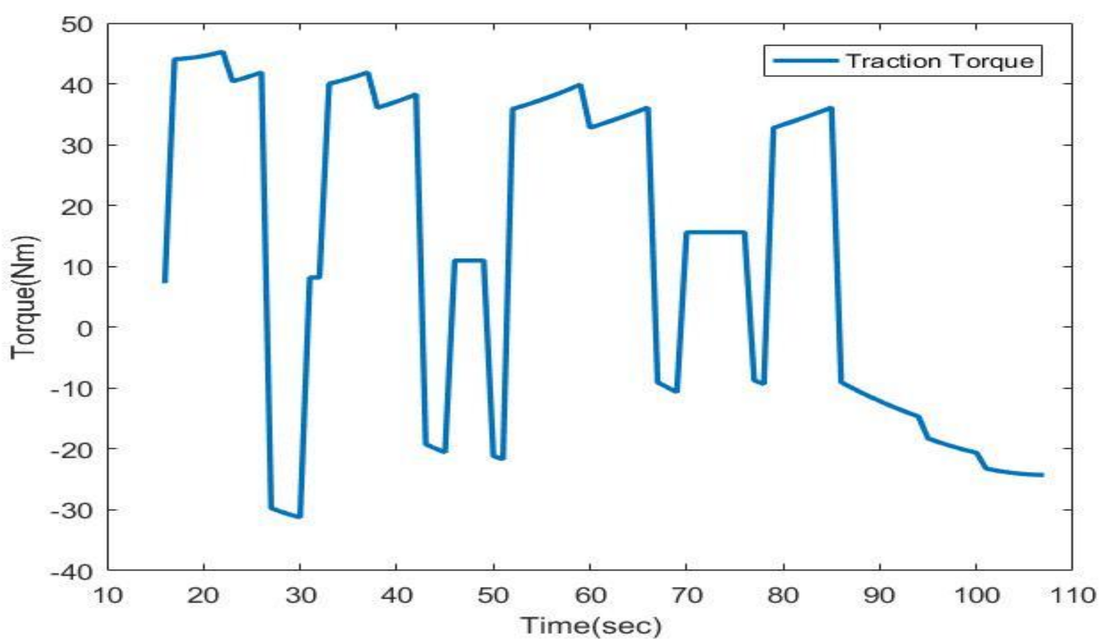

Fig: 9 Graphs Between The Torque (N-m) versus Times (Sec).

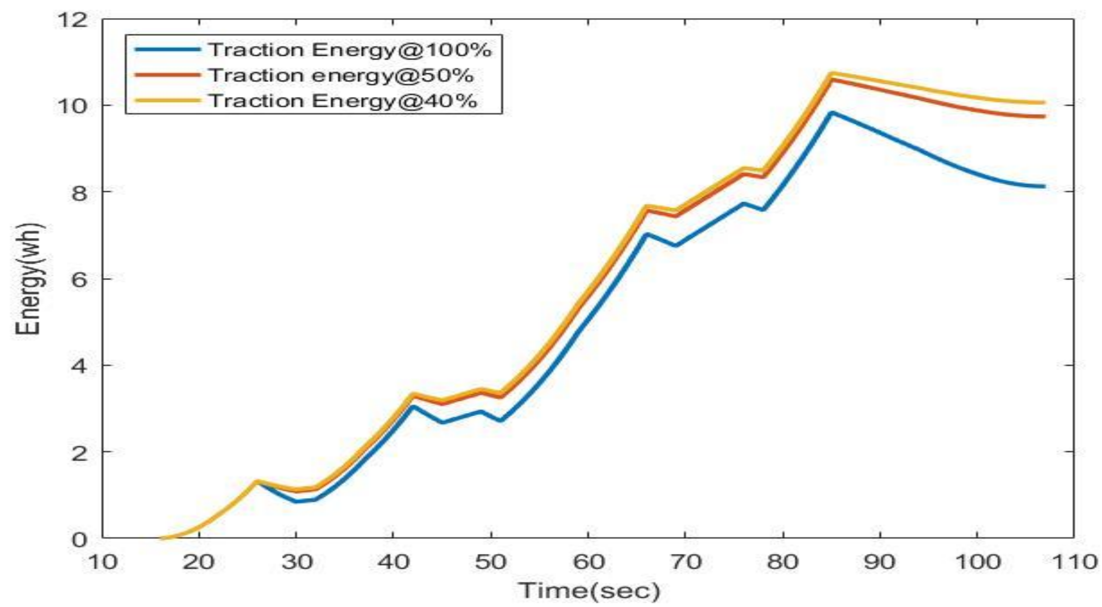

Fig: 10 Graphs Between The Energy Required (wh) versus Time (Sec).

Table: 11.Data collected from MATLAB of the above graph.(e-bike)

Workspace

Name	Value	Size	Max	Min
Acc_Force	*92x1 double*	92x1	118.6094	-127.0833
Acceleration	*92x1 double*	92x1	0.6481	-0.6944
Drag_Force	*92x1 double*	92x1	35.0205	0
ebike	*92x25 double*	92x25	NaN	NaN
Roll_Force	*92x1 double*	92x1	23.3380	23.3380
Time	*92x1 double*	92x1	107	16
Trac_Energy	*92x1 double*	92x1	9.8327	0
Trac_Energy40	*92x1 double*	92x1	10.7414	0
Trac_Energy50	*92x1 double*	92x1	10.5900	0
Trac_Force	*92x1 double*	92x1	146.0306	-100.7454
Trac_Pow	*92x1 double*	92x1	1.3263e...	-519.0393
Trac_Torque	*92x1 double*	92x1	45.2695	-31.2311
velocity	*92x1 double*	92x1	11.3888	0
Velocity	*92x1 double*	92x1	40.9998	0

From the above table and graph we can calculate the value of forces, power and energy at different time and different speed SO, form the above data we can say that the maximum power required to drive the e-bike is 1.3263kw and the torque required is 45.2695 N-m. But this drive cycle is limited for max speed 0f 41km/hr.

Our main purpose for using this drive cycle is to calculate the actual energy consumption. And from the graph and above data we can easily observe that the total energy required to drive the e-bike is 8.1235Wh, 9.735Wh.and 10.05781Wh.which is different at different regeneration. These energies are required for the distance of 0.658km in 108 sec. But why we are getting the different values of energy consumption and the answer of this question is due to the regeneration of energy at the time of deceleration of vehicle .So let us understand the concept of regeneration .

3.3 Regenerative Braking System:

When the electric vehicle is in motion then it carries the kinetic energy and momentum. But at the time of slowing down of vehicle at the time of traffic and at the time of breaking this energy is wasted. Because according to the first law of thermodynamics Energy neither be created nor destroyed it can only changes to one form of energy to another form. So, at the time of breaking this kinetic energy is converted to friction and thermal energy and lost to the environment.

But by using the concept of regenerative breaking system [15][16] this energy can get back to the battery with the help of motor. In an Electric Vehicle, as motion of the vehicle stops accelerating, the power train automatically engages a regenerative braking system to cover the loss of energy due to deceleration to transfer the energy back to the motor which now acts as the generator to recharge the battery. This energy conversion is done by the motor of electric vehicle and the working principle behind this conversion is as mention below and Regenerative braking occurs in both DC and induction motors. In a DC shut-off motor, when the decelerating speed is less than the no-load speed, the electromotive force exceeds the supply, producing a negative current in the armature and thus converting the motor into a generator, in the case of series, It is used in the case of constant motion when the electromotive force does not exceed the supply voltage, thus used in lift hoists, a common method of converting a series motor to a shunt motor.

In the case of an induction motor, when the speed of the motor is greater than its synchronous speed, the electric current reverses because at this point the relative motion between the conductors and the gap in the air while the phase angle is increased and greater than that respectively. 90°. Also in the case of low speeds, regeneration with a change in frequency can be achieved.

In this thesis paper we have assumed the three efficiency of regenerative braking i.e. 100%, 50% and the 40% but 100 % is not possible because there must be lost of energy we cannot convert the whole energy but we can achieve 40% and 50 % SO, we can observe from the fig 10. That when there is 100% regeneration then the energy required is less and as the regenerative efficiency is decreasing then the energy consumption is increasing.

Range of Electric Vehicle:

Total Consumption of energy @ 100% regeneration =8.1235Wh.

Total Consumption of energy @ 50% regeneration =9.735Wh.

Total Consumption of energy @ 40% regeneration =10.05781Wh.

Distance Travelled in 108 sec =0.658Km.

From equation (10) we know that the energy consume per km is calculated as[2]:

$$= \frac{(Total\ Consumed\ energy@40\%)}{(Total\ Distace\ travelled)}$$

$$= \frac{(10.05781)}{(0.658)} \text{ (Wh/Km)}$$

$$= 15.28 Wh/km.$$

And if we will take the losses, Auxiliary power and the efficiency of motor to be 80% then the energy required per km would be like 20 Wh/km.

So the range of electric vehicle = $\frac{(Energy\ Of\ Battery)}{(Consuption\ of\ energy\ per\ km.)}$ -------------------- (11)

$$= \frac{(2500)}{(20)} = 125\text{Km.}$$

From above we can say that from 2.5kwh of battery we can run a bike for 125km.In India 1 unit of energy equal to 1000wh and it will cost up to 8 rupees. So, to charge the battery of 2.5kwh it will cost only 20 rupees. And one can drive a bike for 125km in just 20 rupees. But the initial cost of li-ion battery is too high and they have also some charging life cycle .This is not for life time so we have to calculate these all to find the cost per km required to drive e-bike.

3.4 Drive Cycle for E-rickshaw:

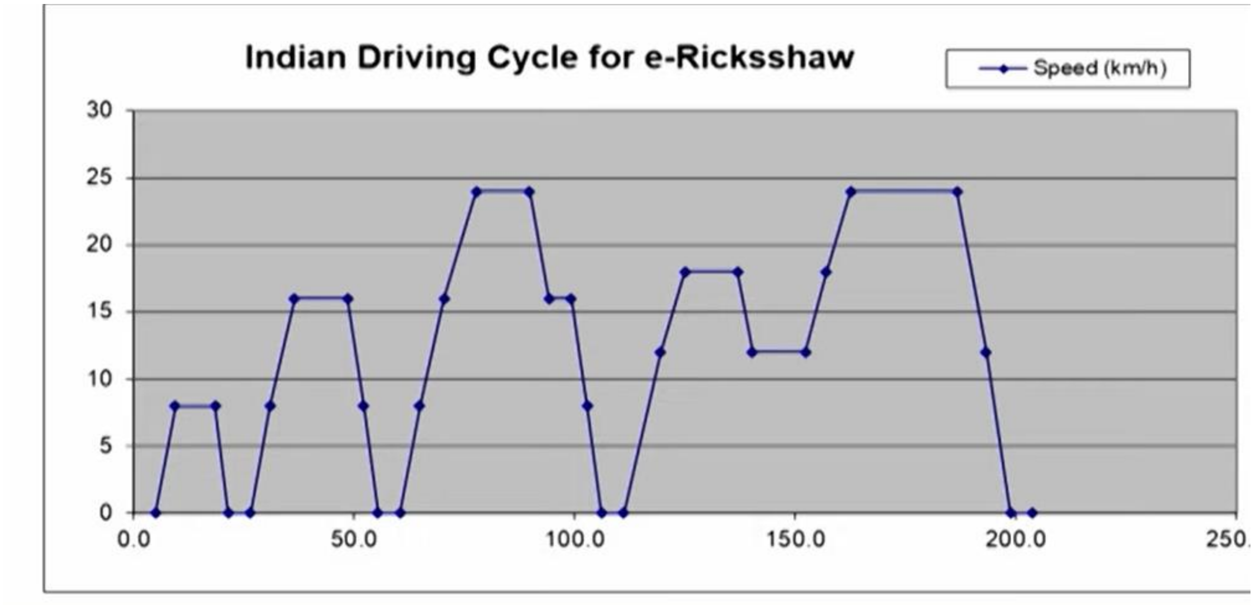

Fig: 11 Indian Drive Cycle for e-Rickshaw.

From the above Graph we can calculate the the velocity, Acceleration and Deceleration of E-rickshaw at the specific time like what we have done for e-bike. And then we will put all these value in the above equation then we will get the desire force, power and energy required to drive the e-rickshaw.

Table: 12 Velocity, Acceleration, Deceleration of 1DC (e-rickshaw).

No. of Operations	State/Position of e-rickshaw	Cumulative time(sec)	Velocity (Km/hr)
1	Idling	5	0
2	Acceleration	9.4	8
3	Steady Speed	18.4	8
4	Deceleration	21.4	0
5	Idling	26.4	0

6	Acceleration	30.9	8
7	Acceleration	36.4	16
8	Steady Speed	48.4	16
9	Deceleration	52.1	8
10	Deceleration	55.3	0
11	Idling	60.3	0
12	Acceleration	64.8	8
13	Acceleration	70.3	16
14	Acceleration	77.7	24
15	Steady Speed	89.7	24
16	Deceleration	94.2	16
17	Steady Speed	99.2	16
18	Deceleration	102.9	8
19	Deceleration	106.1	0
20	Idling	111.1	0
21	Acceleration	119.4	12
22	Acceleration	124.9	18
23	Steady Speed	136.9	18
24	Deceleration	140.3	12
25	Steady Speed	152.3	12
26	Acceleration	157	18
27	Acceleration	162.6	24
28	Steady Speed	186.6	24

29	Deceleration	193.3	12
30	Deceleration	198.8	0
31	Idling	203.8	0

Maximum Speed during the Drive Cycle is 23.516km/hrs.

Distance travelled during this drive cycle is 0.727km.

Average Speed during this drive cycle is 11km/hrs.

Now we have the velocity, Acceleration, Deceleration and the desire time. So by putting these all value in the above Equation from equ.1 to equ.10 we can get the different forces like drag force, rolling force, Acceleration force. And also we know that the power required driving the e-rickshaw is calculated by multiplying the force with the velocity. And we can also calculate the torque required to drive the e-rickshaw by multiplying the force with the wheel of the e-rickshaw. All the calculation done in this paper by the MATLAB programming.

Table 13: Battery Specification of E-Rickshaw:

Sr. No.	**Specification/Parameter**	**Value**
1	Battery Type	VRL(Lead Acid Battery)
2	Capacity	12Ah-120Ah.
3	Voltage	12 V
4	Weight	30kg
5	Charging Time	6 – 8 hrs

The Voltage of one battery pack is 12V but we need 48V to drive the E-rickshaw so we will connect this battery in series to get the desire voltage. The weight of one battery pack is almost 30kg then the 4 battery will sum up to 120 kg. And the weight of loading (4 passengers + 1 driver + their luggage) is equal to 400kg and the remaining is the mass of E-rickshaw so The Gross mass of e-rickshaw is 680kg.Now putting these all value like the mass, velocity, acceleration, and the specification of E-rickshaw we can get the all forces, power and the desired energy required to drive the E-rickshaw [9][10].

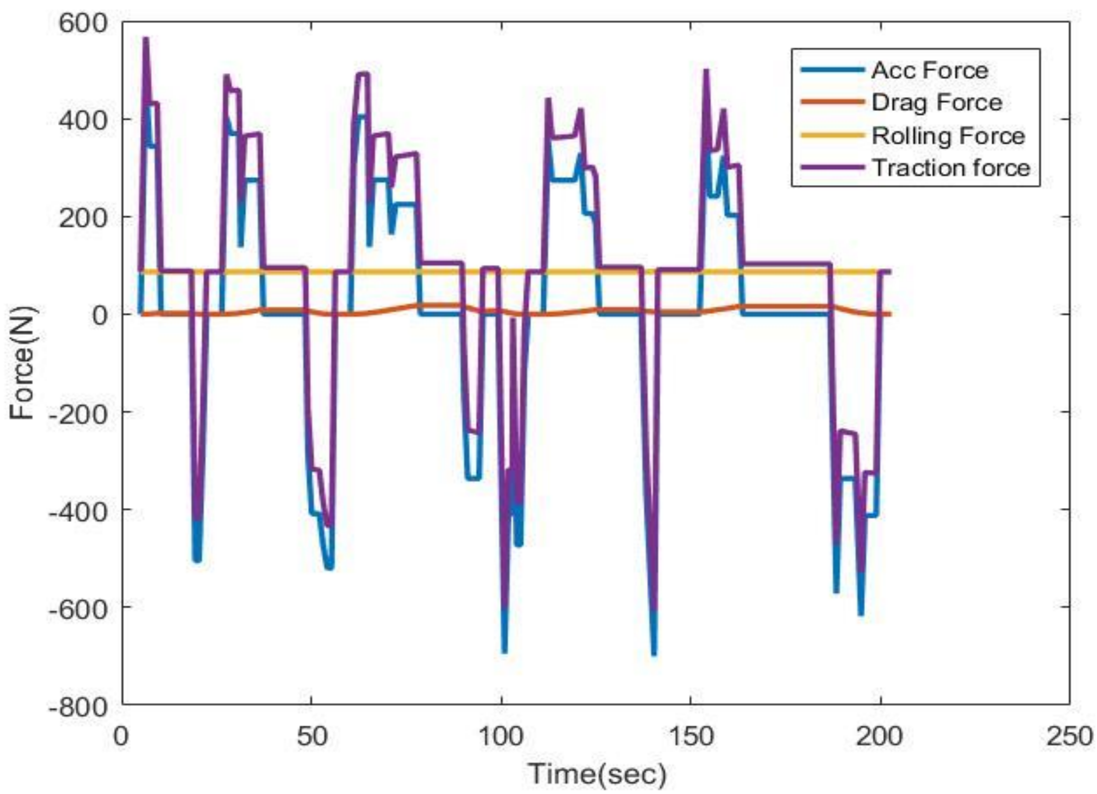

Fig: 12 Graph Between The different Forces (N) versus Time (Sec).

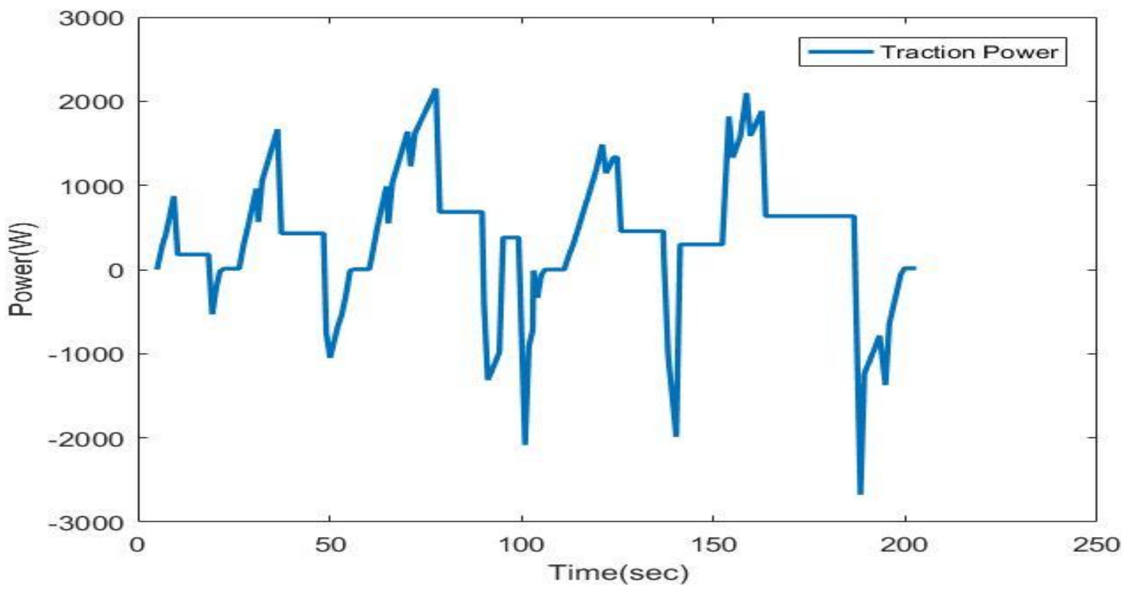

Fig 13: Graph Between Power (W) versus Times (Sec).

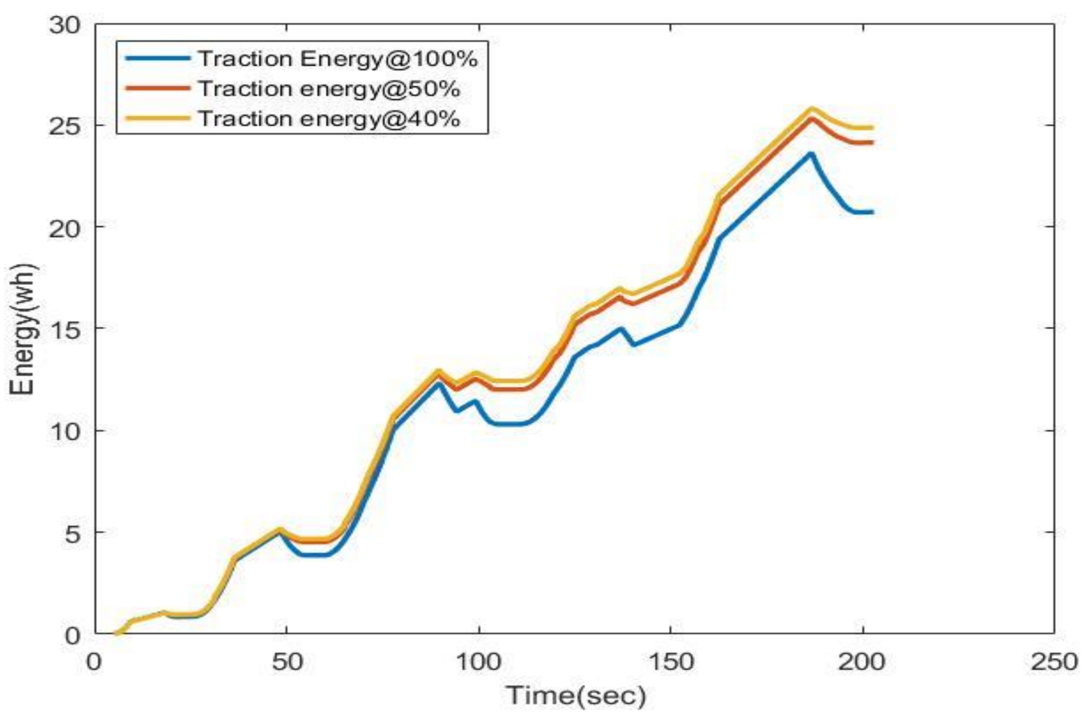

Fig 14: Graph Between Energy (Wh) versus Times (Sec).

Table 14: Data Collected From MATLAB (E-Rickshaw).

Workspace

Name	Value	Size	Max	Min
Acc_Force	194x1 double	194x1	343.4344	-504.3333
Acceleration	194x1 double	194x1	0.5051	-0.7417
Drag_Force	194x1 double	194x1	18.0249	0
ebike	194x22 double	194x22	NaN	NaN
Roll_Force	194x1 double	194x1	86.7204	86.7204
Time	194x1 double	194x1	202.8000	5
Trac_Energy	194x1 double	194x1	22.8394	0
Trac_Energy40	194x1 double	194x1	25.8210	0
Trac_Energy50	194x1 double	194x1	25.3241	0
Trac_Force	194x1 double	194x1	431.8787	-417.4912
Trac_Pow	194x1 double	194x1	2.0169e...	-1.4135e...
velocity	194x1 double	194x1	6.5324	0
Velocity	194x1 double	194x1	23.5167	0

From the above Table and Graph we can conclude the magnitude of different Forces, Power and the energy required to drive the E-Rickshaw. The maximum Power required to drive the E-Rickshaw is 2.0169KW. And the efficiency of motor is 80% So, A motor of 2.5KW is required to drive the E-rickshaw. And the total Energy required to drive the E-rickshaw at 40% regenerative braking For this drive cycle is 24.89 Wh .According to this drive cycle the distance travelled by E-rickshaw is 0.727km in 204sec.Now we can find the energy consumption per km by using the equation (10).

$$= \frac{24.89}{0.727} \text{ Wh/km}$$

$$= 34.236 \; wh/km.$$

If we consider the losses, and Auxiliaries devices and the inefficiency of devices and overall efficiency would be 80% then the energy consumption would be 43wh/km.

3.4.1 Range of E-rickshaw:

Total energy of battery bank is 48V*100Ah i.e. 4.8kwh. And the range is calculated with the help of equation (11) ..

$$= \left(\frac{4800}{43}\right)\text{km}$$

$$= 110km.$$

The Range of E-rickshaw is 100 to 110km with 4.8kwh battery bank.

3.5 Range Extension of Electric Vehicle:

Range extension means increasing the original range of electric vehicle by any external source and it is known as range extender. It will continuously charge the battery so the discharge rate of battery will decrease and it will take more time to discharge the battery and the range of electric vehicle will increase .So for this we need to know about the discharge rate of electric vehicle, How the battery are draining so that we can charge the battery in that way. So for this we need to draw the curve of SOC (State of charge) .

And after getting the SOC curve we can charge the battery by two way i.e. in 1st way we can start the Auxiliary power unit when the SOC come to some 70% to 80% .Then the AP will automatically start and charge the battery with the help of alternator and the 2nd way is we can continuously charge the battery like when the power consumption per km is 16wh then we will charge the battery be like 4wh or 8wh so the drainage of battery will decrease per km, and we can go more distance.

But the life cycle of battery depend upon the number of charge cycle and the c-rate of charging and discharging so, we will go for the second method in this paper. As the c-rate of battery is 0.1 or 0.2 so we will start charging the battery from initial stage and in this way we can increase the life of battery too.

3.5.1 SOC (State of Charge):

SOC is the ratio of the remaining capacity of the battery to the total capacity or it is the level of charge of a battery relative to its capacity. When the battery is fully charged the SOC is 100% and on discharge it is 0%. SOC depends upon many factors like the temperature, and the charging and discharging current of the battery. This is called the c-rate of battery .C-rate mainly is the rate at which the battery is charged or discharged. 1C means battery is discharged in one hrs, 2C means battery will discharge and charge in half hrs.

There are various ways to find the SOC of battery like open voltage method, coulomb counting method, and the Kalman filter method[12]. But in this paper we are using the Coulomb Counting method to find the SOC of battery. The coulomb counting method is also known as ampere hour counting method and it is also known as the current integration method, it is the most common technique for calculating the SOC. This method mainly employs the battery current readings mathematically to integrate over the usage period to calculate SOC and it is given by:

$$= SOC(t) - \frac{1}{C(rate)} \int_{t0}^{t} Ib(t)dt \qquad \text{---------------------- (12).}$$

Where;

SOC (t) = is the initial SOC of battery.

C_{rate} = initial Capacity of battery.

I_b = Battery Current.

Now putting all the values from the battery specification of li-ion battery for E-bike in the above equation then we will get the following graph of SOC V/S Time (Sec) and the Distance (Km). By MATLAB.

Chapter 4

4.1 RESULT AND DISCUSSION:

With the help of all the equation, formulation and data the simulation start with the Range extension electric vehicle running on the repeated Indian drive cycle for both the E- bike and E-rickshaw. First the electric vehicle running on pure EV with the 40% regeneration energy where RE switched off all the time and by doing this the SOC depletion of both the drive cycle is obtained. And the graph were obtained to estimate the REEV driving range until the battery were fully exhausted however in this paper it is shown the depletion of battery till the soc 70% and by repetition of the drive cycle and when the soc of battery become 0% then it is observed that when E-bike run on only on battery (2.5KWh) then the maximum range could be 125km per charge. And for E-rickshaw it is 110Km per charge (4.8KWh). The result of this simulation is shown in fig(15) ,(16) and these result show that the energy consumption of E-rickshaw is more than the E-bike and this is due to the weight and drag force of E-rickshaw.

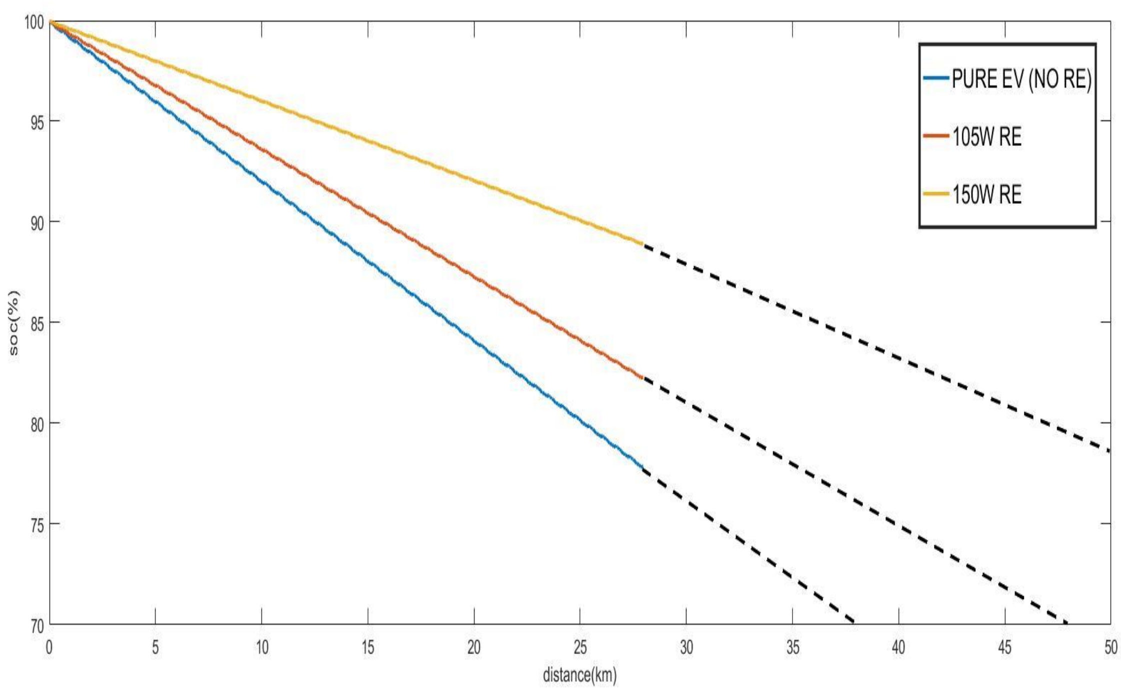

Fig: 15 SOC versus driving range at different RE Power (E-Bike)

Now by switching on the Range Extender (RE) from the starting of the vehicle (when the SOC of the battery is 100%) then we can observe from the fig(15) that the driving range

of E-bike is extended by some distance which is shown in dotted line. When the vehicle is running only on battery then the maximum range is 125km but by using the range extender of 105W the maximum range of electric vehicle is 162.5Km and by using the RE of 150W the maximum range is 187.5Km.

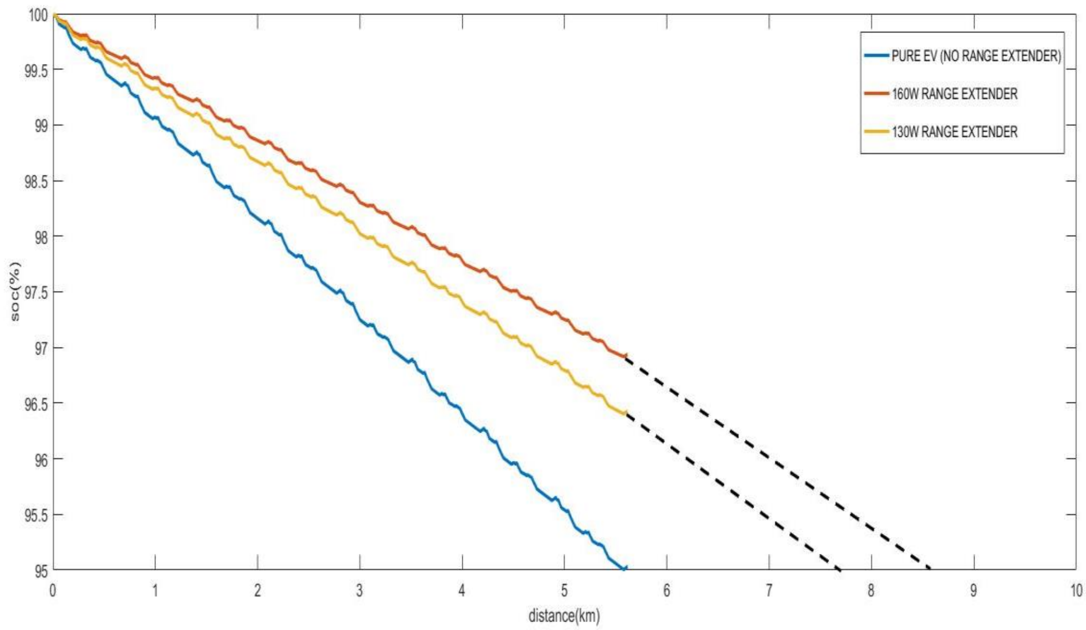

Fig: 16 SOC versus driving range at different RE Power (E-Rickshaw)

From the above fig: 16 it is observed that the 5% of the battery is used i.e. SOC of battery decreases from 100% to 95% when it is used in pure EV mode and the distance travel by consuming 5% of battery is 5.5Km and when the repetition of the drive cycle is done and the soc of the battery become to 0% then the maximum distance travel by E-rickshaw is 100Km to 110Km.

By switching on the range extender from the starting of the running of E-rickshaw the range is extended and it is shown in the dotted line. it is observed from the above fig: 16 that when the soc is 95% and by using 130W range extender the range is extended from

5.5Km to 7.75Km and when this drive cycle is repeated by using the RE then by using the 130W RE the maximum range is 145Km and by using 160W Range extender the maximum range would be 156Km.

4.2 CONCLUSION:

In this paper The Performance analysis and range extension for E-bike and E-rickshaw on Indian road condition is done. A parametric study was conducted to assess the impact of RE Power and battery sizing on the REEV driving range under Indian condition road.

There are two conditions taken the first one is general condition and the second is Indian drive cycle. Because Indian drive cycle is limited for some speed and time. So it is observed in the general case that tills the speed of 40 and 50km/hr 2KW power motor is enough to drive the E-bike but when the speed is 80km/hr or 90km/hr then 7Kw motor is required to drive E-bike and it is also observed that the range of electric vehicle decreased on increasing the weight and velocity of the vehicle. And in case of E-rickshaw the maximum speed is limited to 25km/hr so 1.5 or 2KW motor is sufficient to drive the E-rickshaw.

Now in case of IDC it is found that for the same battery capacity the maximum range of E-bike and E-rickshaw is increase by some distance like in E-bike the maximum range in pure EV mode is 125Km but by applying the range extension of 105W and 150W the distance is increased to 162.5Km and 187.5Km respectively. And in case of E-rickshaw when it is running on pure EV mode the maximum distance is 110Km. But by applying the RE of 130W and 160W the maximum range is increased to 145 Km and 156Km respectively.

The battery capacity which is equivalent to the above mention RE for E-bike is of 750Wh and 1.25KWh and the weight of that battery would be 4Kg and 6Kg so for the desirable result the weight of the RE must be equal to that weight or it must be less than that weight.

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