IMPACT OF ELECTRIC VEHICLES ON INDIAN DISTRIBUTION SYSTEM

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Abstract- Vehicles driven by fossil fuel drastically increases green house gases and air pollution and uncontrolled air pollution is going to deplete ozone layer. For this all governments all over the world is trying to make publicity and promoting electric vehicles to low down percentage of carbon dioxide , carbon monoxide like poisonous gases emission in environment. In this well thought mathematical calculations and modelling and simulations of e-vehicles. The disadvantages associated like more losses, more voltage fluctions , excessive overloading and higher cost. So a reference model is made to design a complete electric vehicle.

***Keywords:** Electric vehicles, MATLAB/Simulink, Mathematical modelling, Load profile*

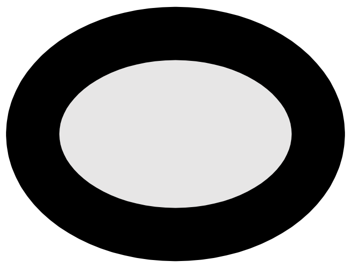
I. Introduction:

Electric vehicles are powered by a rechargeable battery. They have both good as well as a harmful impact on the distribution system. In all vehicles, range and performance are essential. Some features of electric vehicles make the mathematical modelling performance easier than the other vehicles. The first model vehicle performance means its top speed and acceleration. If a better target of an electric vehicle is achieved, the understanding of electric vehicles should be better than fuel vehicles. Another feature of an electric vehicle is range. The range can also be demonstrated.

In this paper, the electric vehicle 'Mahindra e2o' has been simulated. Its performance and range have been analyzed by the simulation results. The mathematical calculation and simulation modeling is developed. And the results are shown in the form of a graph.

Wheel diameter is calculated from the data of the spare wheel.

Tyre dimension=$155/70/R13\ inch$



The total diameter of the wheel=$2 \times (tyre\ width \times side\ wall\ \frac{height}{100}) + (diameter\ of\ the\ rim\ in\ mm)$

$$=2 \times \frac{155 \times 70}{100} + (13 \times 25.4) = 0.5472m$$

Radius= 0.2736 m

II. MATHEMATICAL CALCULATION OF PERFORMANCE OF VEHICLE

To perform the mathematical model of an electric vehicle, its performance and range are important. To move a vehicle, various forces are required, and its total force is considered as a total tractive force. This force is accomplished with rolling resistive force (Frr), aerodynamic drag force (Fad), hill climbing force (Fhc), and acceleration force.

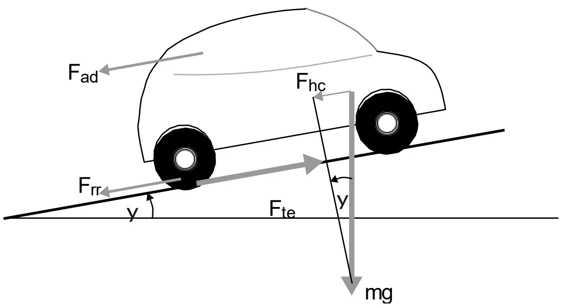


Fig. 1: The forces acting on a vehicle moving along a slope[1]

The velocity of vehicle is 40kmph as considered for the further calculations. The electric vehicle, velocity in meter per second is shown as,

$v = 40 \times (0.2778 m / s) = 11.112 m / s$

The rolling resistive force: This force is due to the friction of moving tyre on the road.

$F_{rr} = u_{rr} * m * g = 0.005 * 1257 * 9.8 = 61.59N$ (1)

Where, F_{rr} is the rolling resistive force

u_{rr} is the coefficient of rolling resistance which is controlled by the tyre and tyre pressure. The typical value of u_{rr} is 0.005

m is the mass of the vehicle

g is acceleration due togravity= $9.8 m/s^2$

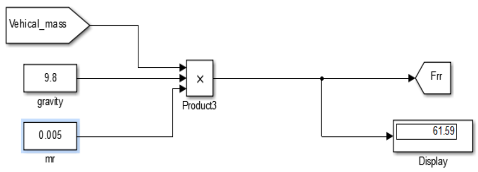


Figure 2: The rolling resistive force

The aerodynamic drag force: This force is due to the friction between moving vehicle andair.

$F_{ad} = \frac{1}{2} AC_d V^2 = 0.5 * 1.25 * 2.4 * 0.3 * 11.11^2 = 54.63N$(2)

F_{ad} is the aerodynamic drag force

is the density of air, humidity.The value of density is 1.25

A is the frontal area of vehicle. It assume to be $2.4m^2$

V is the velocity in m/s

C_d is the drag coefficient called as constant. The typical value of a drag coefficient is 0.36

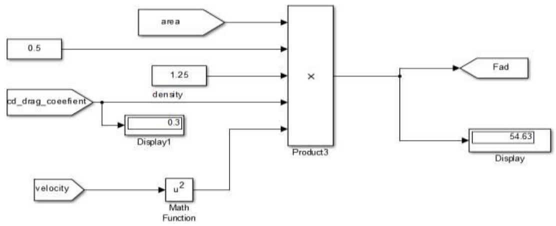


Figure 3: Aerodynamic drag force

The hill climbing force: This force is depends upon the slope of the road. Consider vehicle moving on the flat road.

$F_{hc} = mg\sin(\ ) = 0N$(3)

Here, m is the mass of the vehicle in kg

g is the acceleration due to gravity

is slope of angle

The acceleration force: This force increases with the speed of the vehicle.According to Newtons second law. For the calculation of acceleration motor parameter is to be considered. Assume gear efficiency as 0.98 and gear ratio, torque are given as 10.83 and 70 Nm

$Wheel\ Torque = torque \times gear \times = 70 \times 10.83 \times 0.98 = 742.938Nm$

Force on wheel is given as, $F_{wheel} = \frac{T_{wheel}}{R_{wheel}} = \frac{742.938}{0.2768} = 2684\ N$

Then, $Acceleration = \frac{F_{wheel}}{mass\times} = \frac{2684}{1257\times1.1} = 1.8m / s$

$F_{la} = ma$(4)

The angular acceleration force is required to move a vehicle in angular speed, then the angular acceleration force is

$F_{wa} = I\frac{G^2}{gr^2}a = 74.29Nm$ (5)

I is the moment of inertia = 0.025kg.m^2

$G$is the gear ratio =10.38

r is the radius of the wheel = 0.2736

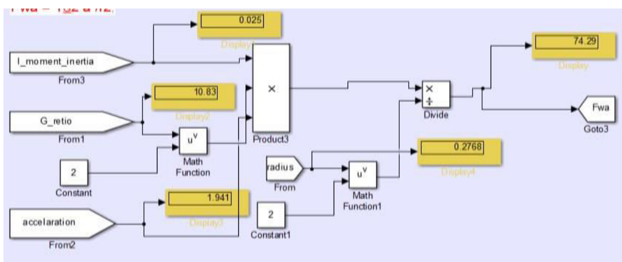


Figure 4: Acceleration force

Total tractive effort: The total tractive effort is the sum of all these forces required to move a prototype of electric vehicle in newton

$F_{te} = F_{rr} + F_{ad} + F_{hc} + F_{la} + F_{wa}$

$= 190.6N$ (6)

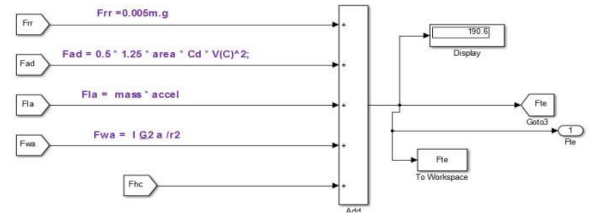


Figure 5:Total tractive effort

III.RANGE MODELLING OF BATTERY ELECTRIC VEHICLES

To expect the value of range, the energy required to move the vehicle in one second is calculated. This process is repeated until battery is null. Consider one-minute time intervals that means energy and the power both are equal.Using various efficiencies, the energy required to move the vehicle for one second is same as the power

$$Energy\ required\ in\ one\ second = Pte$$

$$P_{te} = F_{te} \times V = 2118Watt \quad (7)$$

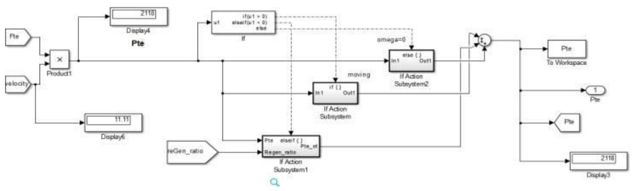


Figure 6:Energy required to move the vehicle in one second

However, if the motor is being used to slow the vehicle, then the efficiency (or rather the inefficiency) works in the opposite sense. In other words, the electrical power from the motor is reduced, and the equation becomes

$$P_{min} = P_{mou} \times {}_{m} = 2505Watt \quad (8)$$

$$P_{mout} = P_{te} \times {}_{gear} = 2161Watt \quad (9)$$

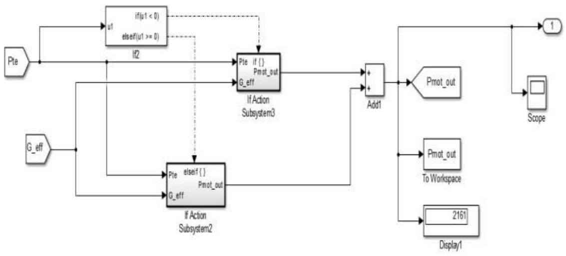


Figure 7: motor output power

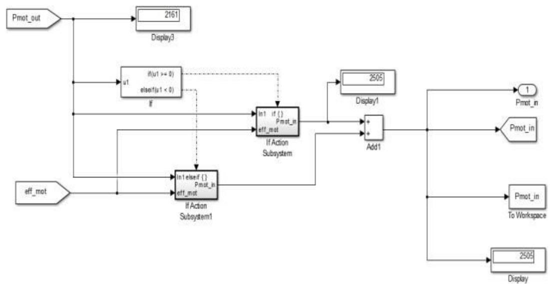


Figure 8: motor input power

The P_{min} gives the electrical power to the motor and thet P_{mout} gives the mechanical power from the motor.

The battery power is the sum of motor input power and accessories power. Consider constant value of P_{ac} is 350

$$P_{battery} = P_{min} + P_{ac} = 2755.2Watt \quad (10)$$

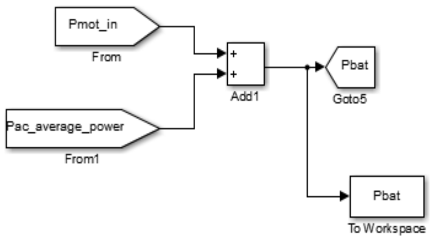


Figure 9:The battery power

If the battery power is greater than zero, the current is calculated as

$$I = \frac{E - \sqrt{(E \times E) - (4 \times Rin \times P_{battery})}}{2 \times I_{in}} = 52.92Amp$$

And, $CR = CR + \frac{I^K}{3600}$

If this condition is not satisfied, the battery power is given as

$$P_{battery} = -1 \times P_{battery}$$

Then, the current is calculated by below formula

$$I = \frac{-E + (E \times E + \sqrt{(4 \times 2 \times R_{in} \times P_{battery})})}{2 \times 2 \times R_{in}}$$

And, $CR = CR = \frac{I}{3600}$

The depth of discharge is the ratio of charge remaining to peukert capacity. which is given as $DOD = \frac{CR}{Peucap}$

Battery is completely discharged when depth of discharge shows 0.99 i.e 1. And distance is given as

$$Distance = D + \frac{V}{1000}$$

Battery Parameters		
	Capacity	280Ah
	No. of modules	16
	No. of cells	64
	On board power	15Kwhr
	Battery weight	112Kg
Motor Parameters (3phase IM)		
	Power	19Kw
	Torque	70Nm
	Controller	600Amp
	Mass(gross wt)	1257Kg
	Top speed	80Kmph
	range	140km
	Spare wheel	155/70/R13

Table1: parameters consider for electric vehicle simulation

IV. SIMULATIONS RESULT

The input is needed from slope, acceleration and speed of a road while the output is shown in the form of total tractive effort, power and depth of discharge and distance covered by the electric vehicle in full charge.

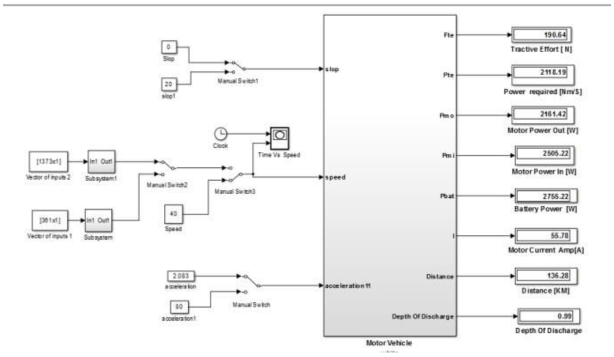


Figure10: The power flow of electric vehicle model

The above figure shows the power flow of electric vehicle model. For testing the electric vehicle, consider speed at 40kmph, with the total mass 1257kg, gear ratio 10.38, it requires motor output power 2161.42watt, motor input power 2505.22watt, battery power 2755.22 watt and distance covered in complete charge is 136.28Km.

A. *For velocity 40kmph*

The various graph shows energy required in one second, efficiency of motor and total distance covered by a vehicletill battery is completely discharged.

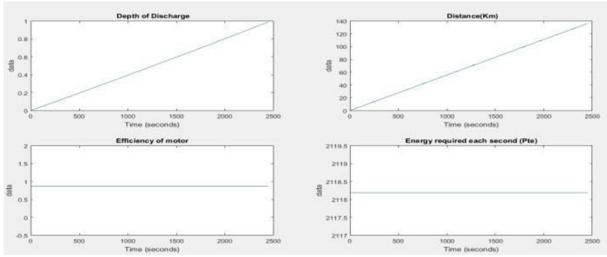


Figure 10: Simulation of energy required in one second, efficiency of motor, depth of discharge and distance

The output of a current and various power i.e. electrical power, mechanical power and battery power is as shown ingraph below.

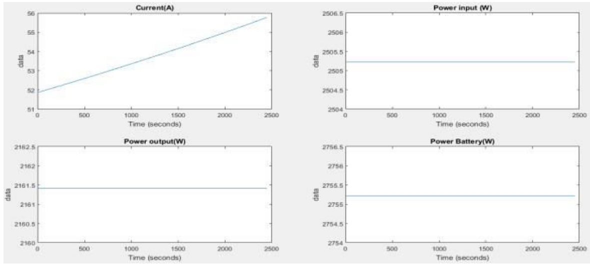


Figure 11: Simulation of electric vehicle model

B. *For vector results*

The results vary with the number of vectors put in the input.

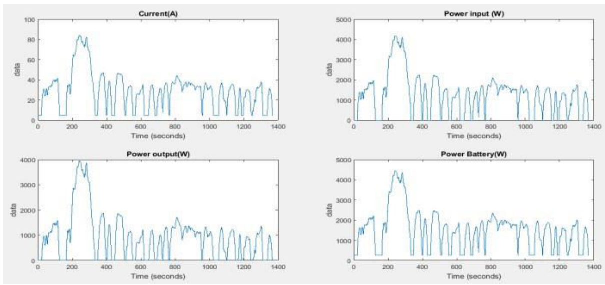


Figure 12: Vector1373, current and power output waveform

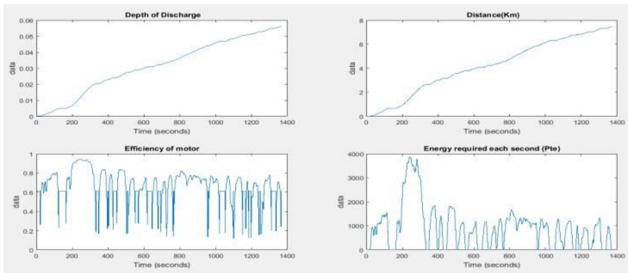


Figure 13: Vector 1373, energy required in one second, efficiency of motor, depth of discharge and distance

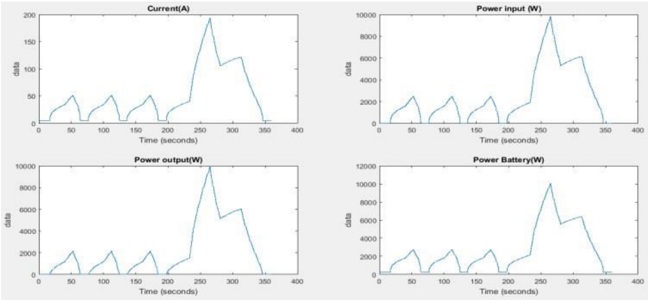


Figure 14: Vector 361, current and various power waveform

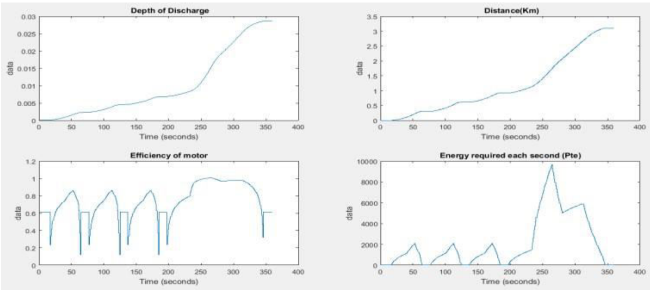


Figure 13: Vector 361, energy required in one second, efficiency of motor, depth of discharge and distance

C. *For regenerative braking*

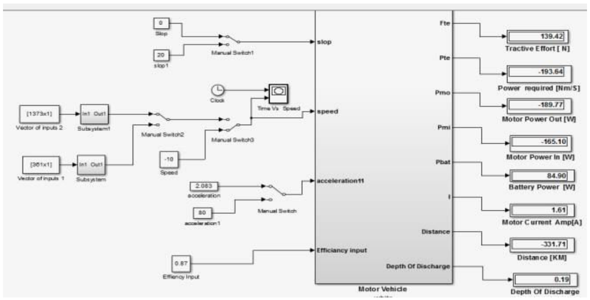


Figure: battery charged through regenerative braking

Whenever the brakes applied, the vehicleautomatically gets charged that means the kinetic energy of the vehicle is converted into electrical energy and chargethe electric vehicle.

VELOCITY	DOD 100%
	Range[km]
40Kmph	136.28
60Kmph	107.32
80Kmph	77.71

Table II. Simulation results for different inputs

Mahindra e2o has give a range of 140 km for complete depth of discharge under ideal condition. The mathematical calculation and simulation result matches nearly to the specified data of electric vehicle.

Case1: Impact on the load profile with EV's uncoordinated charging.

As per the peak load of ola charging station. Divide 200 vehicles with the hight of per hour peak.As per that, distribute these 200 vehicles with various time. According to the peak load of ola and assumed vehicle distributed through it, having maximum peak time 11am to 7 pm. The above vehicle is simulate to calculate range, distance and speed of the vehicle. As per simulation, vehicle having a range of 137km for speed of 40kmph. If one vehicle have four trip in one day, it means, that vehicle require four times charge to complete battery charge. Electric vehicle consume 37 units to full charge.and one unit is similar to the 1kwatt. So, load on electricity increases. As per the graph mention below, the maximum load occours at 1pm which is to be 3108kwatt.If vehicle run at a speed of 40kmph so, it covered a distance of 136.28 km. Similarly, vehicle runs at a speed of 60kmph and 80 kmph, it covered a distance of 107.32km and 77.72Km respectively. Due to various losses occour in the system, and increases the the speed of the vehicle, its range and depth of discharge affected. Battery get easily null.Total distance covered by vehicle is the product of range and the per day trip of the vehicle. So, at the four trip of range 136.28km,vehicle covered a distance of 545.12lm.For the load profile 200 vehicle is to considered. These 200 vehicles are varied with time. At different time, various number of vehicles are come at charging station. Maximum numbers of vehicle come at charging station between 11am to 7pm.In this scenario, the impact of electric vehicle on the load profile with uncoordinated charging is seen.In this case, it is assumed that most of the vehicles are charged between 11am to 5pm in different charging station as per the vehicle owners suitability. Thus, this time is considered as the best time of charging for electric vehicle batteries. Hence, due to the charging of electric vehicle between 11am and 5pm, the loadincreases and load profile is at the peak. Therefore, this case is considered as uncoordinated charging of electric vehicle. The uncoordinated charging substantially increases voltage unbalance of the distribution system.

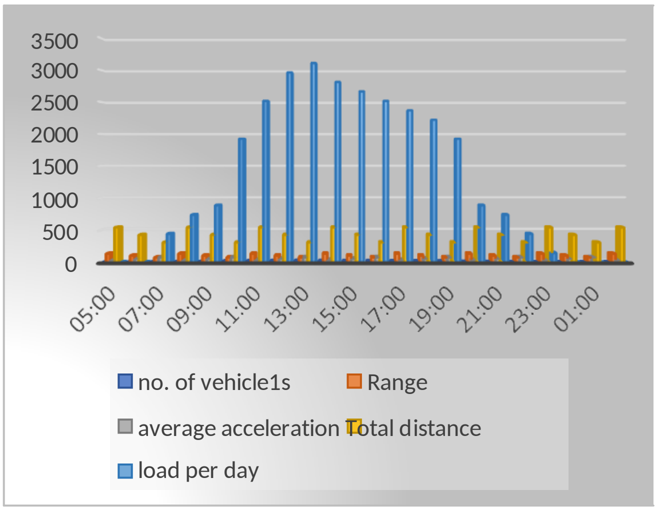


Fig: Load profile of uncoordinated charging of EV

From the above graph it is clear that, the peak load is at 777kw due to uncoordinated charging.

Case II: Impact of coordinated charging of electric vehicle

To reduce the problems of uncoordinated charging system, coordinated charging is used. In the second scenario, the load on the distribution system is distributed with respect totime. In this case, it is assumed that the electric vehicle owner charges their vehicle during base load period. Means from 6am to 6pm instead of 11pm to 7pm. Due to this load of uncoordinated charging is distributed with time.And the peak load get flatter. In the coordinated charging load from 3108kwatt shifted to 2072 kwatt. Hence,1036kwatt electricity saved.Due to this, peak load period gets flatter. From the above graph it is seen that the load curve is flatter as compared to uncoordinated charging system.For time period 6am-6pm,fourteen no. of vehicles is to be consider. After 6pm, no. of vehicles reduces.

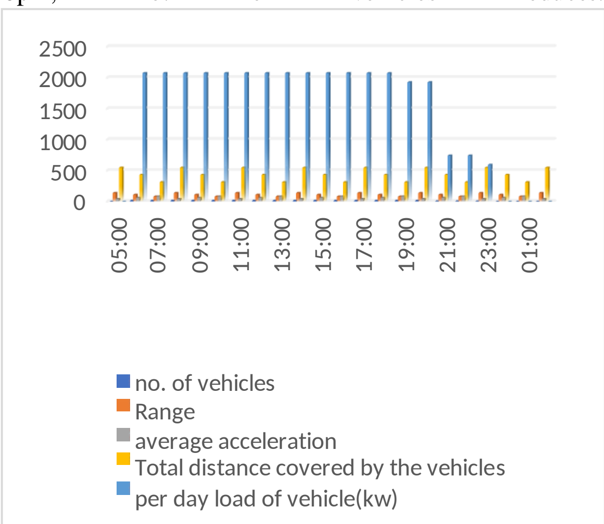


Fig: Load profile of coordinated charging of EV

V. CONCLUSION:

In this paper, the analytical calculation of electric vehicles is presented. And simulation model of electric vehicles was developed in MATLAB/Simulink. To design a separate model of an electric vehicle, one has to spend time as well as money. This paper gives a ready design model of electric vehicles, which will help the manufacturer to develop electric vehicles easily.It can be assumed that electric vehicles will increase in the next few years. Therefore, load on the distribution grid will increase tremendously with the sudden demand for more electricity in order to charge these vehicles. This can be controlled through proper management of the charging system with respect to time.

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