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Experimental Analysis and Simulation of Electric Vehicle using Lithium-ion Battery

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Abstract: *Electric mobility is getting attention all over the world due to the increasing environmental concerns. Day-to-day use of fuel is increasing due to its consumption by the vehicles and other industrial uses. This massive use of fuel has given rise to the fuel prices. Also, India features among the top four nations using the greatest number of two-wheelers all over the world. Maharashtra is using the greatest number of cars in India. Delhi, Mumbai is the top among using two-wheelers in India. This shows the massive utilization of vehicles which results in high consumption of conventional fuels which are decreasing day by day. All these facts are contributing in increasing air pollution. Nearly 25% to 30% of total green-house gases emissions in world are due to transportation industry. This fuel consumption results in production of harmful gases like C02, NO2, NO and CO which causes environmental damage and has adverse effect on human health. To avoid these emissions electric vehicles were introduced. Electric vehicles can be powered by electric motors. As it runs on electricity, vehicle emits no exhaust gases and is environmentally friendly. EV employs electric-drive technologies to boast vehicle efficiency. The different types of batteries such as Lead acid, lithium ion, nickel bromide is used as an energy storage for electric vehicles. Lithium batteries are used as a mode in EV as they have higher densities than lead-acid batteries. Compared with other commonly rechargeable batteries like Ni-Cd, Ni-MH and Lead-acid battery, the lithium-ion battery is featured by high energy and power density, long service life and environmental friendliness and, thus, has been widely applied in consumer electronics It is a type of rechargeable battery in which lithium ions move from the negative electrode through an electrolyte to the positive electrode during discharge, and back when charging. Li-ion batteries use an intercalated lithium compound as the material at the positive electrode and typically graphite at the negative electrode. The present work is focused on the analysis of lithium-ion batteries with DC motor in an electrical vehicle using simulations and a scale model to compare and check different parameters like the state of charge of the battery, voltage, current, average speed of the vehicle, etc.*

Keywords: E-mobility, Types of Batteries, Lithium-ion Battery, Average Speed, Simulation, etc.

I. INTRODUCTION

Problem Statement

Increasing transportation sector and using conventional fuel at high rates has given rise to several environmental problems and financial crisis. Due to increasing cost of non- conventional fuel using more energy efficient vehicles like electronic vehicles and hybrid electronic vehicles is a way from which the above problems can be solved at a certain level. Moreover, the electronic vehicles are cheaper to run as a cost of electricity required to charge an electric vehicle is around 40% less than cost to use petrol for same sized vehicle at the same distance. Lithium-ion battery is most preferred in this process as it has greater density and has longer life as compared to others. Ion batteries use a negative electrode principally made from carbon (e.g., graphite) or lithium titanate, with some novel materials under development, namely, Li metal and Li alloys.

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The above report consists study and analysis of the working setup and calculations of the electric vehicle lithium-ion battery as a storage system and comparing the working model with simulated model.

Objectives

1. Literature survey on various electric vehicle for getting idea about to know earlier work done and to know scope for further work.
2. Cad modelling of proposed setup with assumed parameters.
3. Battery and motor calculation for proposed setup to get efficient working parameters like soc (%), current, voltage variation with respective time for different connection at charging as well as discharging condition.
4. Cost estimation of various hardware required like battery, motor and various electronic devices.
5. Simulation study of proposed electrical vehicle using MATLAB Simulink 2020a.
6. Experimental study of proposed electrical vehicle using fabricated setup
7. **Comparative analysis of experimental setup for validation of proposed idea.**

II. STRUCTURAL ANALYSIS

Vehicle Chassis:

The above chassis used is hollow structure made from stainless steel (W2) weighing approximately 22 Kg. The chassis was also powder-coated for its anti-rust property.

Motor:

The motor used is BLDC motor. It specifies characteristics such as:

- Power = 750 W,
- RPM = 500, Weighted RPM = 400
- Operating Voltage = 48 V
- Brush-less

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SOC Meter:

The mentioned SOC meter provides charge percentage of battery and other aspects such as headlight, ON/OFF.

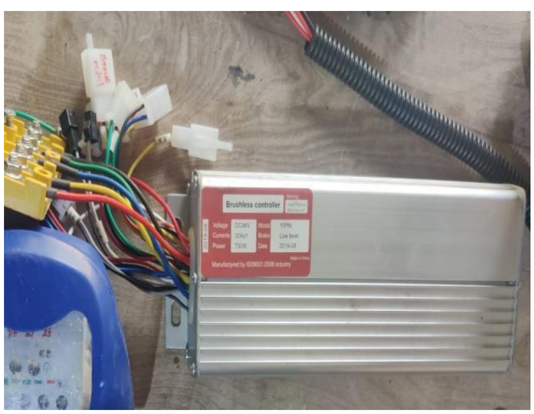
Battery:

Lithium-Ion battery cell is being taken for use as it serves the purpose

Specifications:

- Operating Voltage = 3.7 V
- Current = 2.5 Ah

Brushless Controller:



Brushless controller is added in the structure for controlling the motor. It controls motor by converting signal coming from throttle.

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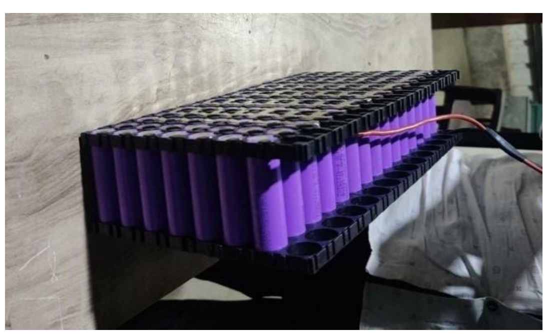
Drive Mechanism:

Transmission of vehicle is based on this drive mechanism.

Rear Axial Transmission:

Motor drives the shaft at the rear which makes the system rear wheel drive. The shaft rotates with the gear at end which powers the wheels.

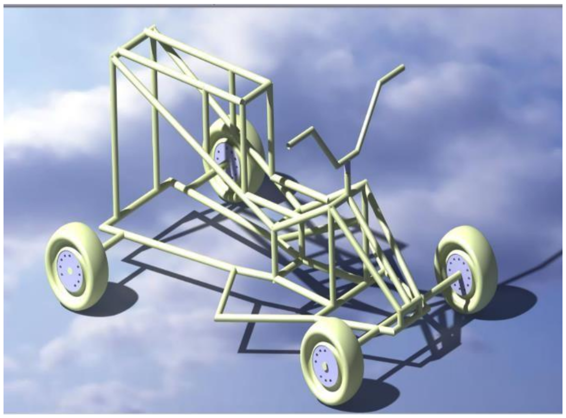
Battery Pack:

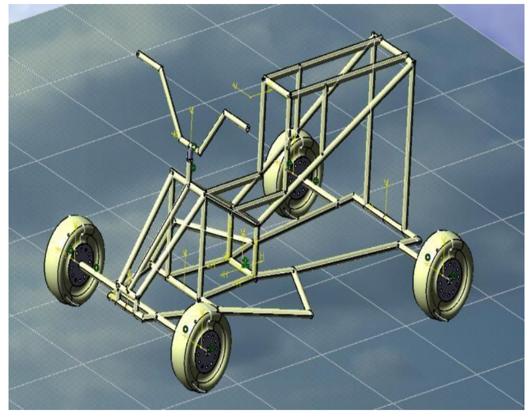


It consists of combination of 91cells in parallel-series combination.
Specification = Operating Voltage = 48V

- Current = 18 Ah
- Length = 208 mm
- Breadth = 112 mm

Cad Model of The Proposed System (Software used: CATIA V5)





Motor Calculations:

To design a car carrying a load of 150 kg and to run at maximum speed of 30 km/hr.

Resistance force (F)

F_{total} = $F_{rolling}$ + $F_{gradient}$ + $F_{aerodynamic\ drag}$

$F_{rolling}$ (rolling resistance) = Cr.m.a.

Cr = coe of rolling resistance m = motion of vehicle in kg

a = acceleration due to gravity (m/s^2) Cr= 0.01, m= 150 kg, a= 9.81 m/s^2 $F_{rolling}$ = 0.01 x 150 x 9.81

[$F_{rolling}$= 14.71 N]

Power required to over rolling resistance = $F_{rolling}$ x (velo. of vehicle m/s) = 14.71 x 30{1000/3600}

= 122.62 ≈ 123-watt Gradient resistance,

$F_{gradient}$ = m.a.sin(θ)[consider (θ) = 0 ° at flat surface] $F_{gradient}$= 0 N [zero]

$F_{aerodynamic}$ = 0.5x ρ x v^2 x C_A x A_F P = Density of air medium

P = 1.23 kg/m^3 (for air at sea level) V = Velocity of vehicle in m/s

V = 30 km/hr = 8.33 m/s

C_A = coe of air resistance C_A = 0.25 (for car)

A_F = frontal area of vehicle (in m^2) How to calculate frontal area of vehicle, Multiply height and width of car.

Adjust volume – Rounded corners for cars = 85%, Brakes = 70% [Assumed length = 68.6cm, width = 58.5cm]

Af = (Height x Width) x Adjusting volume = (0.68 x 0.58) x 0.85 Af = 0.33524 m2

Faero drag = 0.5 x ρ x v2 x CA x Af = 0.5 x 1.23 x (8.33)2 x 0.25 x 0.33524 = 3.576 N

Power required to overcome this air resistance = 2.575 x velocity = 2.575 x 8.33 = 21.44 = 25 watt

So total power required to overcome these resistance forces will be equal to total power required to move vehicle.

Power needed for motor = F(roll power) + gradient + power = 123 + 0 + 25 = 148 watts ≈ 150 watts

∴ To design an electric car of 150 kg and to run at maximum speed of 30 km/hr we need 150-watt motor.

Battery Calculations:

→ Motor = 750 W [calculated]

Calculations: - [battery] [specifications- Power = 750 w, V= 48 volts] Step 1: Current [In Amp] consumed by motor to run

→ Power = Voltage x Current 750 w = 48 volts x Current = 15.625 amp ≈ 18 amp

Step 2: Find out watt how of battery to run 750 watt for 2 hours

Simply multiply (750 w x 2 hours) = 1500 watt/hour Take efficiency of 80% (Li-battery)

i.e. (1500/0.8) = 1875 watt/hour

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Step 3: Convert Watt hour of battery into Ampere hour Power = Voltage x Current
Watt/hour = Voltage x Ampere 1875 = 48 x Ampere
Ampere hour = 1875/48 Ampere hour = 39.06 ≈ 40
∴ To run 750 W motor for 2 hours, 48 volts and 40 Ah lithium-ion battery is needed.
Total Battery Composition Required = 48V/ 18 Ah Battery cell of lithium-ion battery = 3.7 V/ 2.5 Ah
To meet the requirement of voltage we have to make a battery pack by using parallel-series combination.
Batteries in Series [for voltage]
Total Voltage = 48 V 1 Cell = 3.7 V
Total Cell required = 48/3.7 = 13 Therefore 13 cells are required in series. Batteries in Parallel [for ampere]
Total Ampere = 18Ah
1 Cell = 2.5 Ah
Total Cell required = 18/2.5 = 7 7 Cells are required in parallel.
Therefore, for a battery pack of parallel-series combination Total Cells Required = 13 x 7 = 91
As above calculation, required battery pack should be in parallel-series combination, consisting of 91 cells.

I. III. SIMULATION OF BATTERY & MOTOR CONNECTION

Difference between batteries connected in series vs connected in parallel

A. Simulink Circuit for battery series:

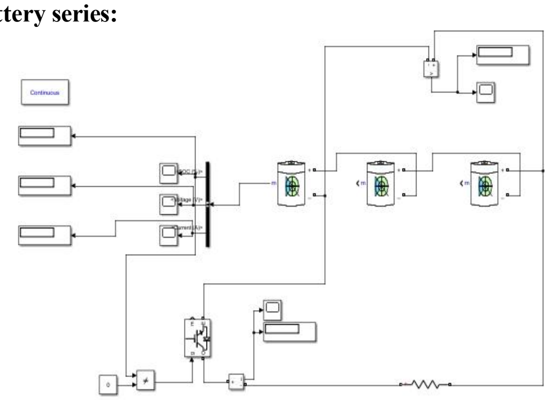

Fig: Simulation model Lithium Ion batteries connected in series

B. Simulink Circuit for Battery Parallel:

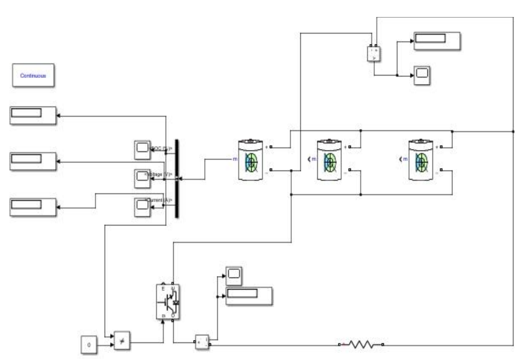

Fig: Simulation model Lithium Ion batteries connected in parallel

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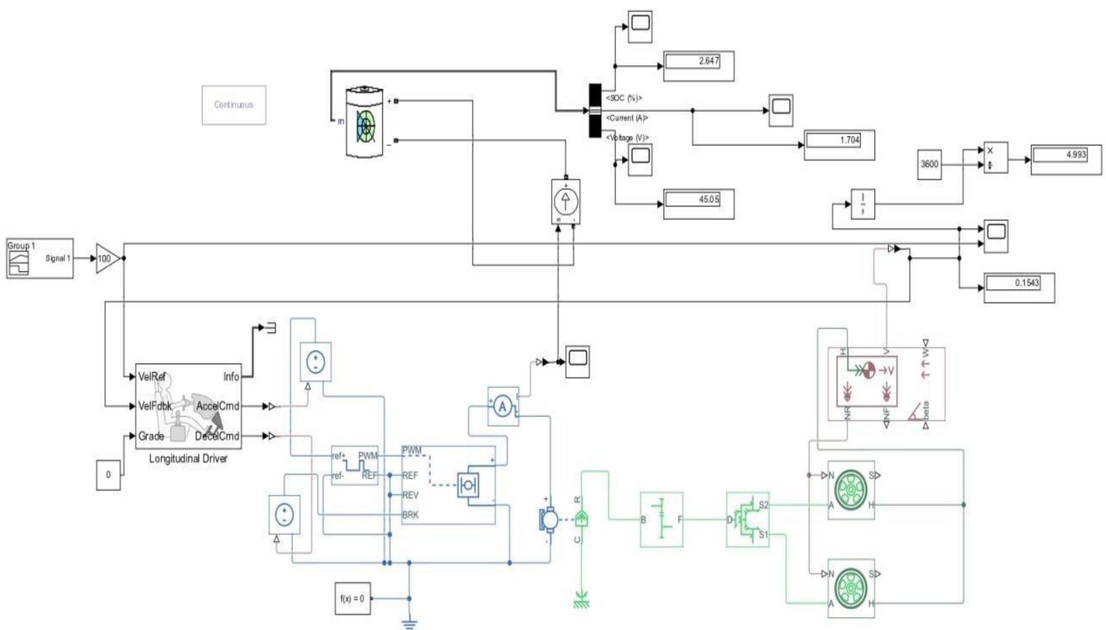
Input Parameters for simulation of calculated values:

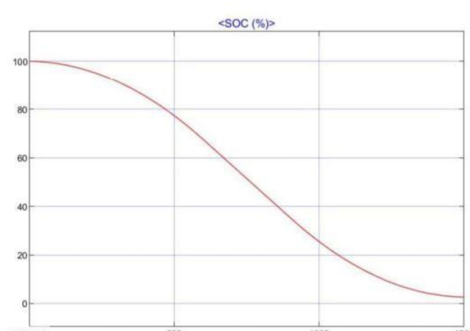
Software used: MATLAB / Simulink version 2020a	
Time of simulation 1500 seconds	
Battery used Lithium-ion battery Specification • Nominal voltage 48V • Rated capacity 18Ah • Initial stage of charge 100% • Battery response time 30 seconds • Efficiency = 80%	DC motor Specification • Rated power of motor - 750 W • Rated rpm of motor – 400 rpm

Results of Simulation:



Simulation model of Electric vehicle

SOC (%)



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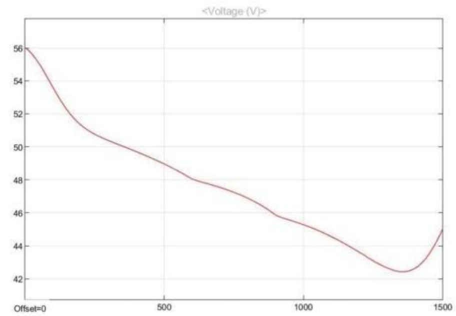
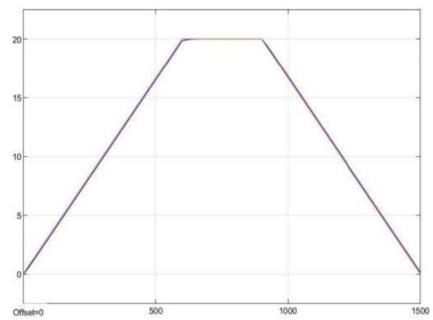
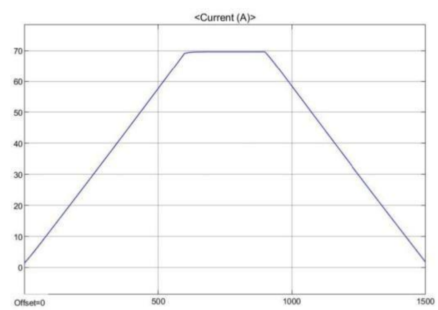
Voltage (V)



Speed vs Time Graph



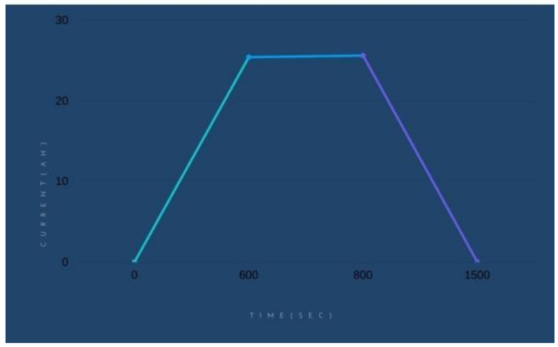
Current (C)



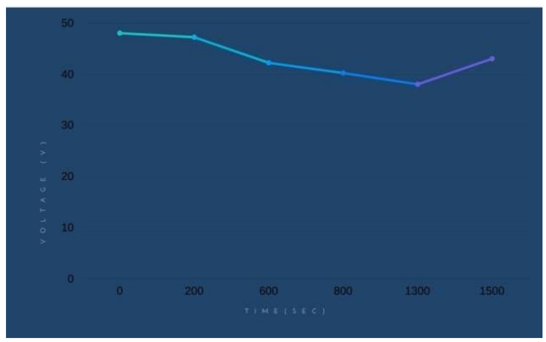
Working Model Readings and Results

Surface of Road	Distance (km)	Speed (Km/hr)	Voltage (V)	Current (Ah)
Flat	1	12	47.2	8.7
	1	15	46	11.6
	1	20	42.2	25.4
Incline	1	10	45	19.6
	1	14	41.5	22.2
	1	18	38.7	26.4

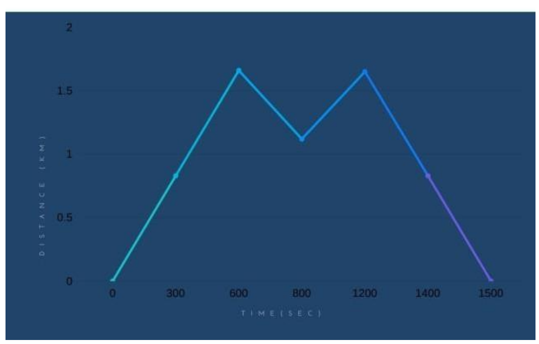
CURRENT V/S TIME



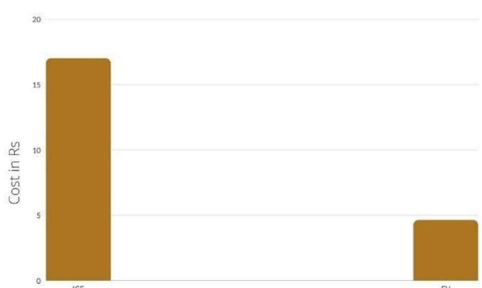
VOLTAGE V/S TIME



DISTANCE V/S TIME



EV V/S PETROL VEHICLE COST



Comparison of Working Model with Actual ICE Vehicle

Data calculated by running both vehicles for 25 min.

ICE Vehicle	EV
Cost per litre = 110 rs	Cost Per Unit = 5 rs
Run Time = 25 min	Run Time = 25 min
Average Speed = 15 kmpl	Average Speed = 15 kmph
Distance Travelled = 6.25 kms	Distance = 6.25 km
Cost of fuel as per distance = 17.19 rs	Cost of fuel as per distance = 4.63

As per distributed data:

Cost of ICE vehicle is 17.19 Rs as compared to EV which costs 4.63 Rs.

Therefore, according to the data shown in above graphs and above-mentioned table, EV proves to be more efficient than ICE vehicle.

IV. CONCLUSIONS AND FUTURE SCOPE

Conclusions

1. According to calculated dimensions of the chassis the cad model has been prepared.
2. The battery pack calculation required to run the setup successfully has been calculated.
3. To run the setup successfully with estimated load high voltage and current is required due to which parallel series combination of battery pack is prepared.
4. The physical structure model has been prepared successfully.
5. The simulated model and physical structure are compared.
6. Running cost of an EV is successfully proved to be lesser than ICE vehicle.
7. The minor differences in simulated data and experimental data are because of factor likes gradient change, ambient temperature, aerodynamic drag, frictional resistance to the road surface and carrying weight of the driver.

Future Scope

1. The current mode is purely battery based. Hybridization can play important role in future as it provides an extra fuel source. Lithium-Ion battery can be used in hybridization with combination such as supercapacitor, solar, CNG, Hydrogen cell etc.
2. Using IOT, by programming we can manufacture smart vehicle which will be capable of performing by remote control, automatic switching to hybridization combination, GPS tracking, autopilot driving
3. Smart and easy charging can be introduced by using EUSE (Electric Vehicle Supply Equipment) which communicate with CMS (central management system) to manage user authorization, billing and rate of charging.
4. Range of the vehicle can be improved by undertaking two wheels or four-wheel drive.
5. Regenerative Breaking can be added which slowdowns a vehicle by converting kinetic energy into a form that can be either used immediately or stored until needed.

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Final Model

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