Design, Simulation and Performance Analysis of a Battery Electric Vehicle Model

Neha khan, Bhupal Singh

Abstract: ***Electric vehicles (EVs), in today's scenario have become a replacement of conventional mode of transportation as they have shown an ability to minimize the carbon and sulfur emitting fuel operating vehicles. In this study, the components of the battery operated EV (BEV) systems are discussed and a model of BEV on the MATLAB-Simulink platform is simulated. Moreover, the relevant electrical system components as well as its corresponding equations for verification are identified. Furthermore, all simulation results were considered. Thus this study presents a foundation for higher researches in the field of EVs.***

Keywords : Battery Electric Vehicle, Mathematical Modeling, MATLAB-Simulink, Simulation..

I. INTRODUCTION

one of the greatest challenges that is being faced in the world is to meet the exponentially increasing energy demand. Our global energy demand is mounting rapidly. Although no one knows accurately the future of the energy, we still believe that transportation will play a major role in saving our conventional fuels and thereby reducing carbon emission considerably.

Today, Electric Vehicles (EVs) are one of the technological progress results that are contributing towards making our lives easier and safer.

Global population, with current trend may increase from 6 billion to 10 billion by 2050 as per estimations. If all the ICVs (Internal Combustion Vehicles) keep on using gasoline or diesel, most of the cities of the world may get covered with permanent smog with extreme air pollution causing sufferings, deteriorating the living environment and increasing health issues in human beings[1].

This paper discusses the simulation of the BEV, its relevant electrical system components and its corresponding equation for verification. In addition, it examines all simulation results. In principal, BEV components include transmission mechanism, electric motor, battery charging controller, driver dynamic model.

II. TYPES OF ELECTRIC VEHICLES

A. Hybrid Electric Vehicles (HEVs)

HEVs as the name suggest use both batteries as well as IC engines[2].

B. Pure Electric Vehicles (PEVs) or Battery Electric Vehicles (BEVs)

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BEVs use only electrical power for their operation. They carry batteries mounted on appropriate place in them[2].

III. COMPONENTS OF ELECTRICAL VEHICLES

The essential components or subsystems for an electric vehicle may be listed as[4,5]:

1. Energy source subsystem (charger, energy management system).
2. Electric propulsion subsystem (controller, power converter, electric motor, transmission gears, wheels, etc).
3. Auxiliary subsystem (auxiliary power, supply power, steering, cooler etc).

ENERGY SOURCES TECHNOLOGIES IN ELECTRIC VEHICLES

If Energy sources used in EVs and HEVs[7]:

1. Batteries (stores energy in chemical form and they have bidirectional power flow).
2. Ultra capacitors (stores the energy in electrostatic form and they have bidirectional power flow).
3. Fuel cell (stores the energy in chemical form it cannot support charging the energy).3
4. Ultra wheels (stores energy in kinetic form and they have bidirectional power flow).

A. Comparisons of various batteries

Batteries	Specific energy (Wh/kg)	Specific power (W/kg)	Cycle life	Cost	Safety
VRLA	30-45	200-300	400-600	Low	--
Ni-Cd	40-60	150-350	600-1200	Medium	--
Ni-MH	60-120	150-400	600-1200	Medium	--
Zn/Air	230	105	NA	Low	--
Na/S	100	200	800	Medium	--
Li-ion	90-160	250-450	1200-2000	High	Concern

B. Types of Li-ion batteries

Li-ion batteries are most commonly preferred at present because of their high specific energy and large cycle life. The prevailing types of Li-ion batteries are:

1. Lithium manganese oxide (LMO).
2. Lithium nickel manganese cobalt oxide (NMC).
3. Lithium iron phosphate (LFP).
4. Lithium nickel cobalt aluminum oxide (NCA).
5. Lithium/sulfur (Li/S).
6. Lithium/air (Li/Air).

C. Battery Charging Technology

1. Normal charging (1-Ph AC, 110-240 V, 13-20 A, 2-4 kW).
2. Opportunity charging (3-Ph AC, 110-240 V, 32-80 A, 8-20 kW).
3. Fast charging (DC, 200-450 V, 80-200 A, 36-90 kW).
4. Battery swapping.

IV. BLOCK DIAGRAM OF ELECTRIC VEHICLE

Basic schematic of BEV is shown in Figure 1.

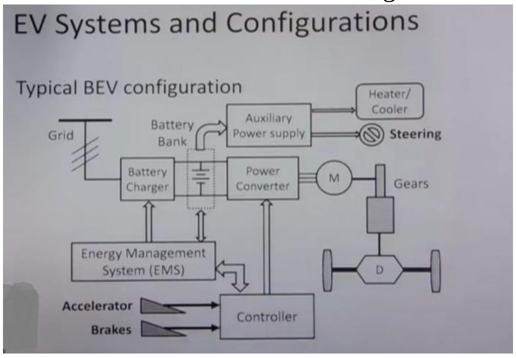

Fig. 1 Block diagram of BEV[8].

V. ELECTRIC VEHICLE DYNAMICS

The Fig. 2. depicts the various forces acting simultaneously upon an electric vehicle.

Tractive effort: The energy required to move/run the vehicle forward is known as tractive effort. The tractive effort force should overcome the following[9,10]:

1. Aerodynamic drag force
2. Rolling resistance force
3. Hill climbing/ drag force
4. Acceleration force

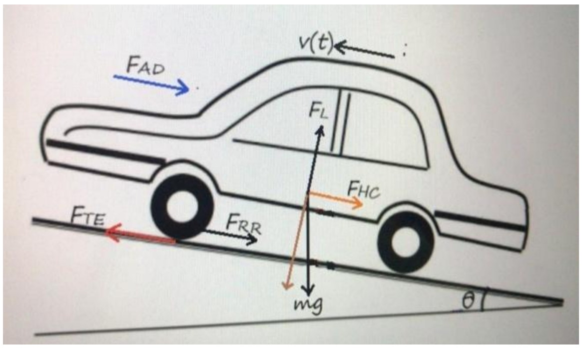

Fig.2 Forces acting upon BEV.

A. Aerodynamic Drag Force (F_{AD})

The force the vehicle body encounters while moving at the certain speed through the air.

$$F_{AD} = \frac{1}{2}\rho C_d A v^2 \quad (1)$$

Where,

ρ = Air density.

C_d = Drag coefficient.

A = Area of application.

v = Velocity

B. Rolling Resistance Force (F_{RR})

$$F_{RR} = \mu_{RR}(P - F_L - F_S) \quad (2)$$

Where, $P = mgcos\theta$ (3)

Lift force, $F_L = \frac{1}{2}\rho C_L A v^2$ (4)

Force due to suspension,

$$F_S = m\frac{d^2x}{dt^2} - k(y - x) - B\left(\frac{dy}{dt} - \frac{dx}{dt}\right) \quad (5)$$

m = Mass of electric vehicle.

μ_{RR} = Rolling friction coefficient.

G = Gravitational acceleration.

θ = Angle of inclination (Slope).

C. Gradeability Force (F_G)

$$F_G = mgsin\theta \quad (6)$$

D. Linear and angular acceleration force (F_{LA} and F_{AA})

$$F_{LA} = m\frac{dv}{dt} \quad (7)$$

$$F_{AA} = J_m\, {G^2}/{\eta_g}\, r^2 \frac{dv}{dt} \quad (8)$$

Where,

J_m = Moment of inertia.

G = Gear ratio.

η_g = Transmission efficiency.

r = Radius of wheel.

dv/dt = Rate of change of linear velocity.

Combining above all equations,

$$F_{TE} = F_{AD} + F_{RR} + F_G + F_{LA} + F_{AA} \quad (9)$$

$$F_{TE} = \left(\frac{1}{2}\rho C_d A v^2\right) + \mu_{RR}(mgcos\theta - F_L - F_S) + (mgsin\theta) + \left(m + {J_m G^2}/{\eta_g r^2}\right) + \frac{dv}{dt} \quad (10)$$

Therefore,

$$\frac{dv}{dt} = \left(\frac{1}{m+\frac{J_m G^2}{\eta_g r^2}}\right)\left\{\eta_g T_m \frac{G}{r} - \mu_{RR}(mgcos\theta - F_L - F_S) - mgsin\theta - 12\rho CdAv2 \quad (11)\right.$$

VI. SIMULATION OF BATTERY ELECTRIC VEHICLE

All mathematical equations that apply each component in the battery electric vehicle simulation were incorporated to simulink-model the BEV. All the transmission model, the electric motor model, he battery charge controller model, the driving cycle, the river model and the longitudinal vehicle dynamics model as shown in Fig. 3.

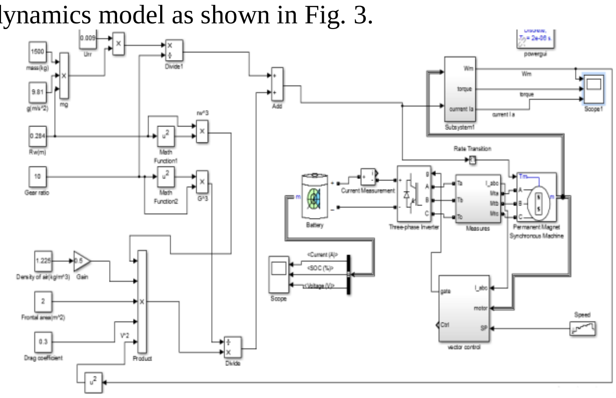

Fig.3 Simulation of Battery Electric Vehicle.

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Table I. Parameters of vehicle dynamics.

Sr. No.	PAPRMETER	VALUE
1	Mass (m)	1200 kg
2	Density(ρ)	1.25 kg/m^3
3	Gravity(g)	9.81 m/s^2
4	Drag coefficient(C_d)	0.34
5	Rolling coefficient(μ_{rr})	0.02
6	Frontal area(A)	2.2 m^2
7	Lift coefficient(C_L)	0.04
8	Inclination angle(Θ)	0-30 degree
9	Gear ratio(G)	10.83
10	Efficiency of gear(η)	0.97
11	Radius of tire(r_m)	0.3 m
12	Inertial mass(m_i)	0.05 of m

Table II. Parameters of motor.

Sr. No.	PARAMETER	VALUE
1	Motor type	3 phase induction
2	Max torque	60 N-m
3	Max power	37 kW
4	Volts	400 V

Table III. Battery Parameters.

Sr.No.	PARAMETER	VALUE
1	Battery Voltage	565V
2	Type of Battery	Li-ion
3	Rated Capacity	120Ah
4	Life Cycle	2-3 year

VII. RESULTS AND DISCUSSION

As shown in Fig. 3 the BEV simulation model has been created by the mathematical equations that are applied by all subsystem blocks.. Fig.4 represents motor speed, motor torque and motor current respectively. Fig.5 represents the battery current state of charge.

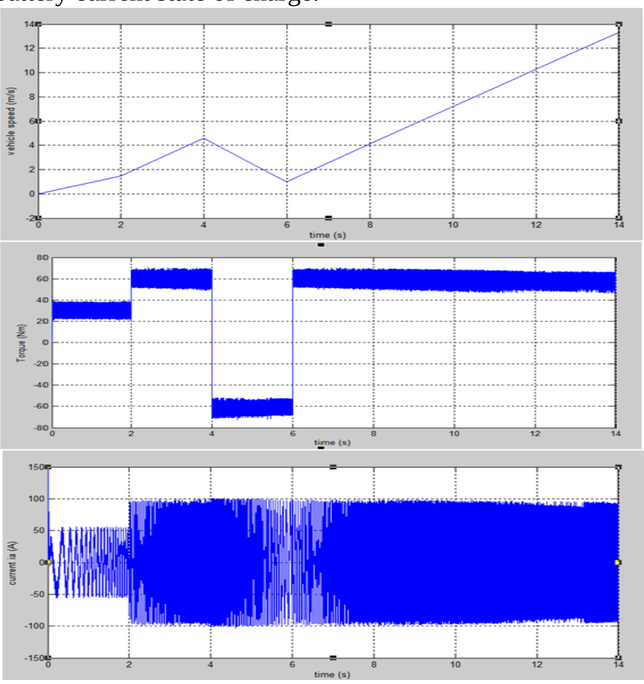

Fig. 4 Responses of motor.

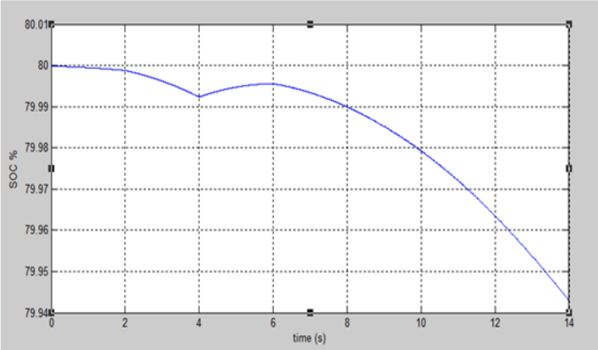

Fig. 5 SOC% of battery.

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Neha Khan is pursuing M.Tech in Electrical and Electronics Engineering from AKG Engineering College, Ghaziabad. She has earned his degree in Electrical Engineering from Dr. APJ Abdul Kalam Technical University, Lucknow (Formerly UPTU).

Dr. Bhupal Singh received the post graduation degree from MNNIT, Allahabad and Ph.D from IIT Delhi. He owns a vast experience of teaching under graduates and post graduates in his career currently he is working as HOD (Electrical and Electronics Engineering) at AKG Engineering College, Ghaziabad. He is the author various research papers in national and international journals. His research area includes Biomedical Signals and Biomedical Instrumentation & Control

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