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MODELING AND SIMULATION OF ELECTRIC VEHICLE DRIVE WITH EVALUATING FORCES

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ABSTRACT—The traditional way of travel is the use of internal combustion engines (IC engines) that run on fossil fuels such as gasoline, diesel, and other similar products; however, these corporate resources are rapidly decreasing. Furthermore, these fuels contribute to pollution and atmospheric anomalies such as global warming. Electric cars' importance and growth have exploded in recent years, owing to the fact that they are pollution-free and more dependable. MATLAB/SIMULINK is a crucial tool for reducing product development costs by facilitating design and specifications. In this article, the electric vehicle drive is modeled, and simulation is carried out using input signals from the SAEJ227 (Society of Automotive Engineers) Japanese driving cycle and the EUDC (Extra Urban Driving Cycle) European driving cycle.The motor voltage, current, and power curves, as well as the battery voltage, current, power, and SOC (State Of Charge) curves, were plotted after the simulation. The model may be used to evaluate the energy flow and capabilities of an electric drive for various driving cycles.
Keywords—Electric vehicle, SAEJ227and EUDC driving cycles, State of Charge, Propulsion

I. NTRODUCTION

Global warming is currently the most serious threat to our planet. One of the major reasons for this is that sophisticated society relies heavily on petroleum derivative-based conveyance for economic and social advancement. According to estimates, more than 1 billion passenger vehicles drive the world's boulevards and streets [1-3]. First and foremost, the globe is grappling with two big issues: energy demand and supply. In 2018, the globe produced roughly 99.3 million barrels of oil per day, according to the International Energy Agency [4]. However, there are up to 1300 billion barrels of known oil reserves. At the current rate of use, the universe will run out of oil in the next 42 years.Second, the globe is in an unwinnable battle with a global environmental disparity. The carbon dioxide (CO_2) fixation in the Earth's climate is increased by the outflows from consuming petroleum derivatives. The increase in CO_2 fixation leads to a rise in temperature and the universe's bizarre climate scenario. The long-term effects of a global temperature increase can be contained inside cost-effective places of confinement. Third, the society need manageability, yet the current approach falls far short.

Reducing the use of petroleum products and reducing carbon emissions are two aspects of a larger effort to ensure that social services are available to all people, have a high level of adaptability, and have an acceptable level of monetary development and prosperity for society. Automobiles powered by energy from clean, secure, and perceptive vitality are essential for this [5].

Vehicles that run on electricity offer a variety of advantages and disadvantages. When compared to the combustion process in a car, electricity is more efficient. According to studies, despite of whether the energy is generated from oil, 1 gallon (3.8 litres) of gas can drive an electric car 108 miles (173 kilometres), compared to 33 miles (53 kilometres) in an internal combustion engine (ICE) vehicle [6-7]. Electricity may be generated by utilising renewable energy sources. However, the current electrical infrastructure places further restrictions on access during the overnight hours, when power usage is at its lowest. Charging electric vehicles (EVs) is ideal in the evenings when the energy system has more power capacity available. The main obstacles with battery-controlled EVs are high costs, limited driving range, and longer charging times. Hybrid electric vehicles (HEVs), which combine an internal combustion engine (ICE) and an electric motor to power the vehicle, outperform pure electric cars in terms of cost and range. In comparison to regular gasoline-powered cars, HEVs can use significantly less fuel. In any scenario, the car continues to run on gasoline or diesel.In comparison to HEVs, plug-in hybrid electric cars (PHEVs) have a larger battery pack and a larger measured engine. In extended range activity, a PHEV functions similarly to a HEV by advancing the powertrain and vehicle foundation activity to achieve improved fuel efficiency using the installed power source and battery. With increased fuel economy, PHEVs may recuperate kinetic energy in the braking phase [11-13].

The following [14-16] can be credited for the recent patterns in EV advancements:

- There is a lot of activity among the main automakers.
- New autonomous makers are a force to be reckoned with.
- Newer models are noticeably superior.
- There is a lot of mobility overseas.
- Hybrid car activity is at an all-time high.
- Particular ICEV to EV transitions are accelerating.

II. ELECTRICVEHICLES

A. Components of anEV

The motor, regulator, power supply, and transmission are the most important components of an electric vehicle's architecture. In electric vehicles, electrochemical batteries have traditionally been the source of power. Due to their well-designed innovation and cheaper cost, lead-acid batteries have remained the preferred choice, despite capable new battery advancements that have been tested in a variety of model vehicles. When a battery's accessible vitality is nearing depletion due to usage, a charger is required to restore the put-away vitality range. The majority of electric cars that have been utilised so far rely on DC, induction, or permanent magnet machinery. Due to the limits of DC machines, EV designers looked into several types of AC machines.In contrast to many designers, the maintenance-free, low-effort induction machines have become an appealing alternative. In any event, acceptance machines' rapid action is only possible with punishment in terms of size and weight.

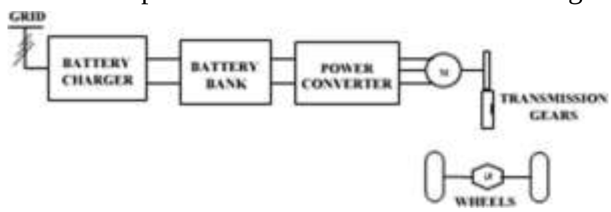

Fig.1. Block diagram of Battery Electric Vehicle (BEV)

Electric Vehicle (BEV). The electric motor is driven by a power electronics-based tool that transforms the constant Voltage to a variable voltage and variable frequency.

B. Types ofEVs

EVs can be classified as mentioned below

1) Based on propulsionsystems

2) Based on energysources.

1. Basedonpropulsionsystems:Thesearecla ssifiedas

i) Pure Electric Vehicles (PEVs): In this, the propulsion system contains the only electricmotor.

ii) Hybrid Electric Vehicles (HEVs): In this, the propulsion system contains both electric motor and engine.

2. Based on energy sources: These are classifiedas

i) Battery Electric Vehicles (BEVs): In this, the energy source used is abattery.

ii) Hybrid Electric Vehicles (HEVs): In this both liquid fuels such as petrol or diesel and battery are used as energysources.

iii) Fuel Cell Electric Vehicles (FCEVs): In this, both battery and fuel cell are used as energysources.

III. ELECTRICPROPULSION

Electric propulsion is the most important aspect of an electric vehicle, and it consists of the electric machine unit, electronics, and power converters. The electrical motor unit provides the majority of the personnel needed to prepare a vehicle. The Power converter is used to provide an electrical contribution based on the machine's immediate need and the coupled burden. The purpose of the electronic controller is to provide command signal to the power converter in accordance with the driver's instructions. As with the growth of semiconductor switches, the size of EVs grew from one to the next. Electrical machines have played a major role in driving various load needs for over a century due to their wide properties. Electrical machines, in comparison to IC engines, have a substantially higher efficiency. Electrical machines may be classified into two groups based on the type of electricity they use: DC and AC machines. Both sets of machines have advantages and disadvantages, and they serve different purposes depending on the load requirements. Most modern automobile manufacturers now use "AC and brushless motors, such as Switched Reluctance Motors, Induction Motors, and Permanent Magnet(PM) Motors."

IV. VEHICLEDYNAMICS

A. The fundamentals of vehicle construction are a direct application of Newton's 2nd law, which describes the relationship between force and acceleration. The car accelerates thanks to the non-zero resultant force. This resulting force is beneficial for opposing the force induced by gravity, air, and tyre blockage [14]. Essential administering components impacting the construction of the vehicle with a focus on electricity were reviewed in this section. The tractive force is the force exerted by the driving unit. Energy and force will be computed after understanding the needed power consumption [15], [19].

B. Vehicle Kinetics

The movement to the vehicle is produced by tractive force (FT). To drive the vehicle, this force must defeat the contradicting force that followed by the vehicle. This restricting force is termed as “road load force, FRL”.

$F_T=F_{ad}+F_{acc}+F_{rr}+F_g=F_{RL}$ (1) Where,

Fad is the force required to overcome aerodynamic drag. Faccis the force required to accelerate the vehicle against inertia.

Frris the force required to overcome rolling resistance. Fgis the force required to overcome gradient.

C. Aerodynamic Drag

When a vehicle passes through an environment, aerodynamic drag is the resistance provided by the air. Aerodynamic drag is divided into two types: 1) frontal drag and 2) skin friction at the body's surface. Aerodynamic drag produces two pressure regions: a high-pressure zone and a low-pressure region, which supply opposing forces as the vehicle passes through the air. The aerodynamic drag's mathematical equation is as follows:

$$F_{ad}=^{1}\times(qC_dA_r)\times(V_v+V_a)^2 \quad \frac{}{2} \quad (2)$$

Where,

ρ is the density of the air.

Cd is aero-dynamic drag co-efficient

Ar is the frontal area Vvis vehicle velocity

The velocity of the vehicle (Vv) in m/s is converted into rpm (Nw) by using

Vais the opposing wind velocity

D. **Propulsion Force**

Itistheforcerequiredtoovercomeacceleration.

N = 60×Vv

2n Rw

The speed of the motor (in rpm) is given by the equation

(8)

Facc=N+(G2×JN×yG)dV
(3)
NM=Nw×G (9)
Where,
r2 dt
The required power is calculated by the equation
P = 2n×NM×TM
(10)
Faccis the propulsion force. m is the mass of the vehicle. G is the ratio of the Gear.
Jm is the motor inertia constant. r is the wheel radius.
ηGis the gear system efficiency. v is the vehicle velocity.
E. Force because ofGradient
Because of the element of slope or slant of the road, this force is created and is given by the numerical equation,
Fg=N×g×sinθ (4)
Where,
Fgis the force required to overcome gradient. m is the mass of the vehicle.
g is the gravitational constant (9.81m/s2).
θ is the angle of the slope.

F. Rolling ResistanceForce

The moving opposition, Frris delivered when the flattening of the vehicle's tire happens when in contact with
60
The motor developed torque is in a linear relationship with armature current.
TM=KN×Ia (11)
Where Km is the motor constant. It is the constraint that is influenced by the motor construction.
The induced back e.m.f (Ea) is proportional to motor speed (md).
Ea=md×KN (12)
The motor input voltage is given by
VK=Ea+IaRa (13)
Ia=IK (14)
The motor power is given by
PK=VK×IK (15)
The voltage at the High side equals K times the voltage at the lowside.

Theroadsurface.Oppositionduetothedeformationoftires
assumes ahuge function in the vehicle elements and
VK = K × VL
(16)
intensive comprehension is required. When the vehicle pushes ahead it results in misalignment of the weight on the

Current at the High side equals 1/K times the current at the low side.

wheel and road normal force. This misalignment prompts a

I = 1 ×I

(17)

couple of forces to apply hindering torque on the wheels. This hindering force couple is named as rolling resistance force Frr.

The mathematical equation for the rolling resistance force is

$Frr=\mu rr\times N\times g\times \cos\theta$ (5)

Where,

Frris the force required to overcome rolling resistance. m is the vehicle mass.

g is the gravitational constant (9.81m/s2) μrris the co-efficient of rolling resistance θ is the slope angle

K K L

The battery voltage is calculated as

Eb,caScuSated=VL+ILRb (18)WhereRbistheresistanceofthebattery.

The battery voltage error is determined by using

BERR=Eb,actuaS−Eb,caScuSated (19)Thebatterypoweriscalculatedbyusing

$P = VL\times IL$ (20)

The consumed A-h of the battery is given by

The wheel torque is obtained by the equation

B =1

3600

× ƒILdt (21)

Where,

$Tw=FT\times Rw$ (6)

SOC means the state of charge and the battery SOC is calculated by using [14]

Tw is the wheel Torque.

FT is the total tractive force

BSOC

= Mas.Æh–ucedÆh

Mas.Æh

(22)

Rw is wheel radius

The wheel Torque (Tw) is converted to motor Torque (TM) by using the followingequation,

V. SIMULINK MODELLING&OBSERVATIONS

In this chapter, the SIMULINK model of the electric vehicle drive is explained. For modelling SIMULINK from

T = (1G×yG

)×Tw (7)

MATLAB is used. The input to the SIMULINK model is the driving cycle of the vehicle. In this paper, we have considered two driving cycles SAEJ227 [17] and the other is

EUDC [18]. We have simulated the model for both the driving cycles and the output waveforms are obtained. SAEJ227 driving cycle is simulated for100 sec and EUDC is simulated for 400 sec. The displaying model has some assumptions to keep work simple, shown in Table 1.

Assumptions:

Specification	Value
Mass of the vehicle	1500 Kg
Gear Ratio	8
The efficiency of the gear system	97%
The radius of the wheel	0.315m
Motor Inertia Constant	0.02 Kg-m^2
Motor Constant	1.7189
Slope	00
Aerodynamic drag co-efficient	0.4
Co-efficient of rolling resistance	0.02
Vehicle Frontal Area	2.2 m^2
The resistance of the motor armature	0.3 Ω
Internal resistance of battery	0.01 Ω
Battery A-h	14 A-h
Battery Internal Voltage	220 V

Table.1. Assumptions in Modelling

The complete simulation diagram is shown in fig. 2. By usingasinglepolesinglethrow(SPST)switchSAEJ227and EUDC driving cycles are given to the input. In the first case, the SAEJ227 driving cycle is given asinput.

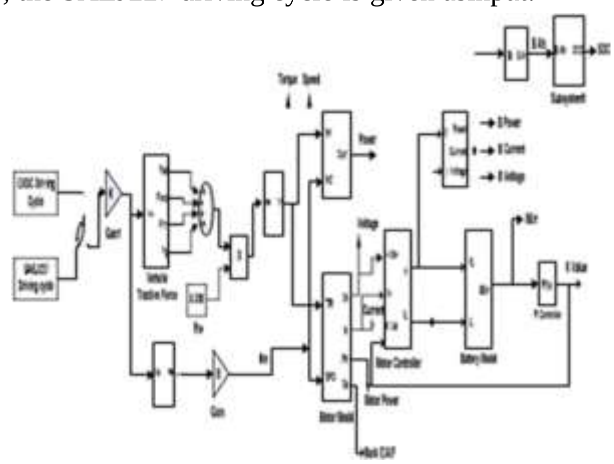

Fig.2. Complete simulation diagram of the model

The driving cycle of SAEJ227 is shown in Fig.3.

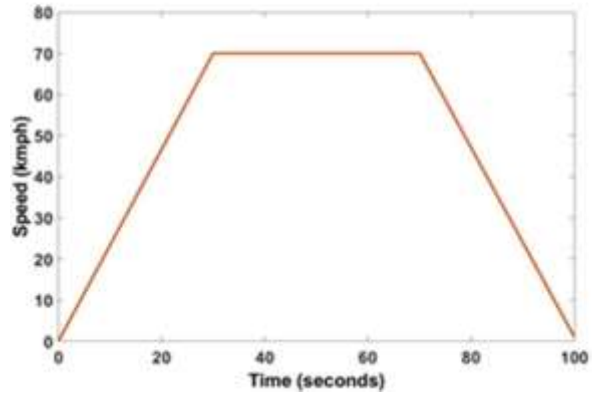

Fig.3. SAEJ227 driving cycle

Aftersimulationdifferentcharacteristicsofmotortorque, voltage, current, power, battery SOC, and battery error voltage are observed and they are shown in Fig.4.

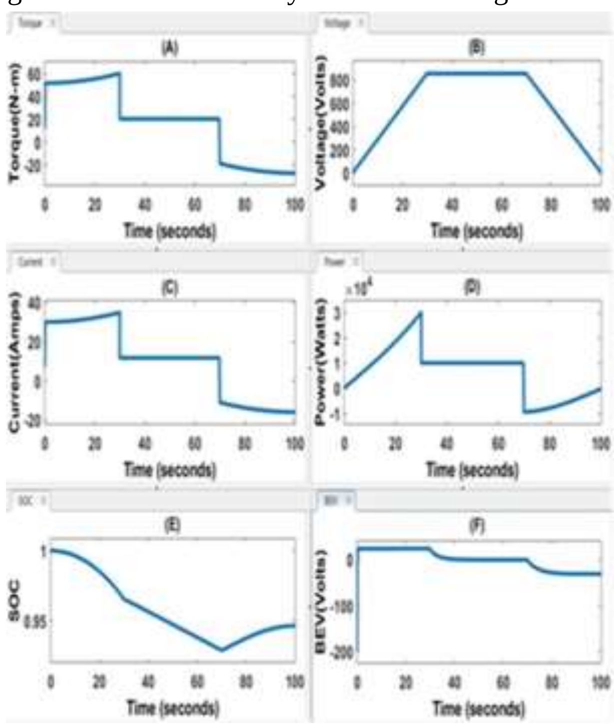

Fig.4. Saej227 (A) Motor Torque (B) Motor Voltage (C) Motor Current
(D) Motor Power (E) SOC (F) Battery Error Voltage

The power moved from the battery to the motor with the same orientation of speed and torque. This is referred to as the driving mode. Power is returned to the battery when + speed and -ve torque are applied. The regeneration mode is what it's called. The highest power required in driving mode for the SAEJ227 driving cycle is 30.2 KW, while the maximum power provided to the battery in regenerating mode is 9.359 KW.

The driving cycle of EUDC is shown in Fig.5.

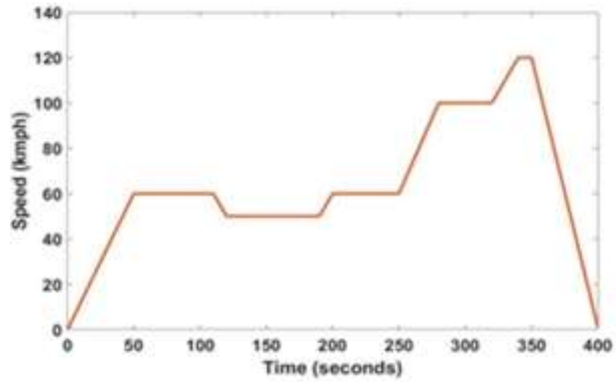

Fig.5. EUDC driving cycle

From Fig.6, different characteristics of motor torque, voltage, current, power, battery SOC, and battery error voltage are observed by giving EUDC driving cycle. For the EUDC driving cycle, the maximum power required in motoring mode is 46 KW and in regenerating mode, the maximum power fed to the battery is 10.04 KW.

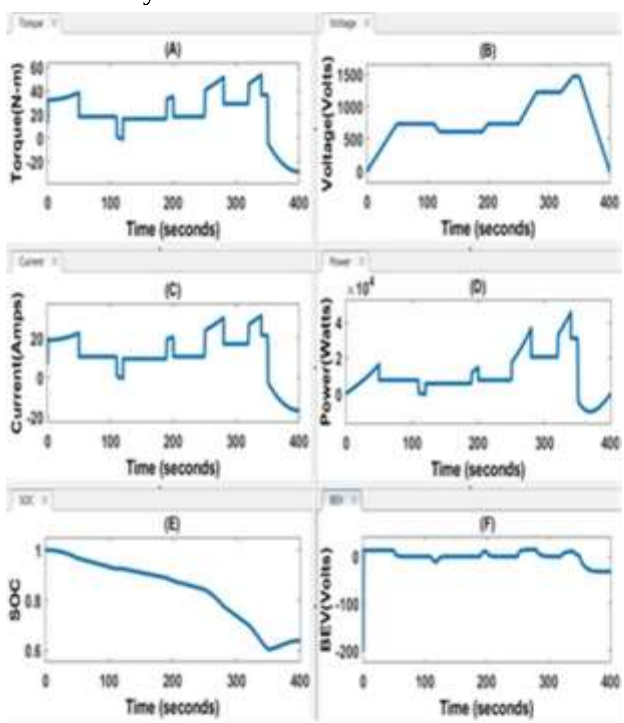

Fig.6. EUDC (A) Motor Torque (B) Motor Voltage (C) Motor Current(D) Motor Power (E) SOC (F) Battery Error Voltage

During driving, the number of Ampere-hours consumed increases, whereas during regeneration, the number of Ampere-hours consumed decreases. The motor current and torque graphs will be identical since torque is proportionate to current. In driving mode, power goes from the battery to the motor, and in regenerating mode, power flows from the motor to the battery. The highest divergence (error) of -199.1 occurs at the time of the simulation's first start. This maximal deviation (error) is a common rebuttal to the model's inception. At the motor primary starting, the model improves immediately and can sustain a variance of +14.71V for the EUDC driving cycle and +24.52V for the SAEJ227 driving cycle. It's very normal to have such a significant inaccuracy because the motor's produced voltage is low at first. We may deduce from the SOC graphs that the battery charge decreases during driving and increases during regeneration.

VI. CONCLUSION

The automotive sector is now transitioning from ICEVs to EVs due to rising air pollution and finite oil reserves. In the future years, electric vehicles will play a larger role in the road transport, leading to a safe habitable planet, Earth.The electric car driving is simulated in this study using basic knowledge about electric vehicles. The model described in this article is simple, easy to implement, and demonstrates a thorough understanding of how to calculate various forces occurring on the vehicle.

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