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Analysis of electric vehicle using MATLAB

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ABSTRACT: The process for modelling an electric vehicle using MATLAB and Simulink software is described in this work. The various Battery, Motor, Power, and Regenerative systems are described in detail here. The planned Electric Vehicle was simulated using Simulink, and various parameters such as Motor Torque, Vehicle Speed, and Battery State of Charge were estimated using different Drive Cycles. For the sake of improving the model, the numerous observed factors were evaluated. Longer-distance vehicles are being manufactured because to advancements in electric motor and battery technologies. As a result, depending on the region and the drive cycle, the performance of these cars can be improved by selecting motors and batteries. The dynamic model of an electric vehicle was developed in this research. The electric vehicle's power consumption and range were calculated using drive cycles such as NEDC, FTP, and WLTC. The impact of variables including battery voltage and energy capacity, motor rated torque and power, and transmission gear ratio on vehicle performance and energy consumption has been investigated.

Keywords: MATLAB/Simulink, Numerical optimization, Simulations, Driving Cycles, SOC, Energy efficiency, Electric Vehicles.

I. INTRODUCTION

Electric vehicles are made up of several models that are linked together to allow the vehicle to function. When developing an electric car, various characteristics must be established, such as the type of motor, battery type, and vehicle dimensions. Various elements such as tyre torque, resistance offered, and battery charge and discharge range. The vehicle's design is critical to its efficiency. Particularly efficient mobility technologies are necessary around the world as part of the transition to a sustainable society. Electric vehicles are widely recognized as such technology.

If the vehicle is more aerodynamically engineered, it will encounter less resistance while driving, which will lessen the load on the motor, allowing it to run more efficiently and provide a longer range. Because different terrains present varying environmental circumstances, the Electric Vehicle is designed to adapt to specific terrains in order to improve vehicle performance. For enhancing the working of vehicle. The main components of the Electric vehicle are Battery and the Motor. The type of engine to use is determined by the driving conditions. It also depends on how much range the vehicle needs. Because there is a steady flow of charge between the motor and the battery, it is necessary for them to sync efficiently. Regenerative System is being offered as we progress in the development of alternative energy sources for running vehicles and supporting the battery model. Because of the regenerative system, when the vehicle brakes, the rotational kinetic energy in the tyre does not immediately stop. The rotational kinetic energy is transformed into electrical energy and stored by the generators in the regenerative system at this moment.

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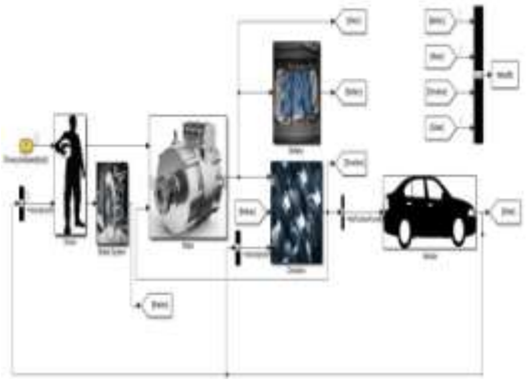

Fig.1. Electric Vehicle Model

History

It’s hard to pinpoint the invention of the electric vehicle to one inventor or country. Instead it was a series of breakthrough—from the battery to the electric motor—in the 1800s that lead to the first electric vehicle on the road. In the early part of the century, the innovators like Hungary, the Netherlands, and the United States—began toying with the concept of battery- powered vehicle and created some of the first small scaled electric cars. And while Robert Anderson, a British inventor, developed the first crude electric carriage, around this same time, it wasn’t until the second half of the 19th century that French and English inventors, built some of the first practical electric cars.

Many entrepreneurs recognized the growing demand for electric vehicles at the time and began developing ways to improve the technology. Ferdinand Porsche, founder of the Porsche sports car company, built the P1 electric automobile in 1898. He also invented the world's first Hybrid Electric Car, a vehicle that runs on both electricity and gasoline. The electric car suffered a setback when Henry Ford's Model T went into commercial production. In 1912, a gasoline car cost $650, while an electric roadster cost $1750. Charles Kettering invented the electric starter the same year, clearing the path for the sale of gasoline-powered vehicles. Gas became affordable after the discovery of Texas crude oil in the 1920s. The 1973 Arab oil embargo generated a growing interest in reducing the United States' dependency on foreign oil and developing indigenous fuel sources in the late 1960s and early 1970s. In response, Congress established the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976, which authorizes the Energy Department to participate in electric and hybrid vehicle research and development.

Around the same time, a number of large and small automakers began researching alternative fuel cars, including electric automobiles. For example, in 1973, General Motors constructed an urban electric car prototype that was displayed at the EPA's first symposium on Low Pollution Power System Development, while the American Motor Company produced Electric Vehicles.

Electric Vehicle

Energy sources, propulsion devices, and energy carriers, which transmit energy from energy sources to propulsion devices, are the three types of electric vehicles.

The Electric Car model is a complete representation of an electric vehicle created in MATLAB using power-train block sets. The vehicle body and tyres, as well as the motor and battery pack, are all covered by subsystems in both vehicle dynamics and electrical systems. The simulation is run with reference speeds, with the manual tweaking of the PID controller tracking the reference speed. As a result, the electric car is more efficient than conventional IC or HEV vehicles. To make the scheme function, however, more public charging stations are required. Electric vehicles employ the electric propulsion system. An internal combustion engine is not required. An electric vehicle has a much simpler structure. The most important components are the propulsion parts:

1. Battery;
2. Drive Cycle;
3. DC Motor;
4. Controller;
5. Vehicle Body and Transmission System.

Components

Battery:

Different types of batteries are mentioned in the table below:

Name	**Values of battery type**				**Unit**
	Li-ion	**Na-$NiCl_2$**	**Ni-MH**	**Li-S**	
Maximum Charge	75	84	85	80	Ah
Nominal Voltage	323	289	288	305	V
Stored	24.2	24.2	24.2	24.2	kWh

energy					
Max./Min. voltage	339/308	275/304	274/302	290/320	V
Initial charge	100	100	100	100	%
Operating temperature	33	270	36	30	^{o}C
Sp. Heat transition	0.4	6	0.4	0.08	W/K
Sp. Heat capacity	795	950	677	1650	$J/kg^{o}K$
Mass of battery	318	457	534	173	Kg
Battery price	300	500	400	250	£

Table.1. battery specifications

The majority of electric automobile technology today uses lithium-ion batteries. Li-ion batteries are a good solution in this business because to their low weight, low energy consumption (14.7kWh/100km), and high energy storage capacity. High operating temperatures can degrade their energy efficiency and limit their lifespan. All of this puts the vehicle's safety at risk.

After examining and comparing the following sorts of batteries, we'll employ Li-ion battery specifications in the research. The battery open circuit voltage Voc and internal resistance R are kept constant throughout the simulation.

Drive Cycle:

Vehicle driving tests and simulations are completed to assist and support the design process in determining if the design is appropriate for the intended purpose. The purpose of the driving cycle is to reduce the number of expensive on-road tests as well as the time and effort required by the test engineer. The road is brought to the dynamometer or the computer simulation by the drive cycle courses.

DC Motor:

The Permanent Magnet Synchronous Motor is mostly found in battery and hybrid electric cars. This motor is used in simulation since it is virtually completely covered in undergraduate engineering education. The motor model has several words and settings for power loss and time lag. The model also accounts for power loss in the winding resistance and time lag caused by energy storage in the magnetic field of the winding inductance.

Controller:

The driving cycle speed is equalized by the PID controller. Between -1 and 1, the PID controller produces. The braking pedal is controlled by positions -1 to 0, whereas the gas pedal is controlled by positions o to 1. With little power loss and no time latency, the motor controller is regarded an ideal controller. To match the higher voltage needs of the motor, the controller simply raises the battery voltage. Both the controlled PVM voltage and the H-bridge block must have the same simulation mode parameter value.

Vehicle Body and Transmission System:

A two-axle vehicle body in longitudinal motion is represented by the vehicle body block. Each axle can have the same number of wheels or a different number of wheels. Due to acceleration and road profile, the block accounts for body mass, aerodynamic drag, road gradient, and weight distribution between axles. Include pitch and suspension dynamics as an option. In reaction to system changes, the mass, inertia, and centre of gravity can alter during the simulation.

Methodology

The components of the electric vehicle battery are designed and integrated using MATLAB. MATLAB offers a robust graphical toolbox that allows users to work in a comfortable and straightforward environment.

The major goal of this study is to compare the drive cycles of different countries within the parameters in order to improve vehicle efficiency. It's also about determining what needs to be improved. With this analytical approach, improvements in electric vehicles may be made, and it can be used to meet the demands and desires of consumers. It also

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contains useful information on the components, process development, and drive cycle implementation.

Major System

To model an EV three major parts of the system need to be considered: 1. Vehicle dynamics; 2. Transmission performance; and 3. Battery.

1. VEHICLE DYNAMICS:

Studying the vehicle dynamics is the initial stage in modelling an electric car. This diagram depicts the net forces operating on a vehicle during its driving cycle, as well as their effect on its velocity and performance. Aerodynamic drag F_{ad}, acceleration, rolling resistance F_{rr}, and hill climbing F_{hc} forces are all included.

Parameters	
Air Density	1.25 kg/m^3
Gravitational Force	9.81m/s^2
Coefficient of Rolling Resistance	0.001
Air drag Coefficient	0.3
Efficiency of Gear System	0.95

Table.2. Vehicle Dynamics

1.1 Aerodynamic Drag Force:

The aerodynamic drag force is the first force acting on the EV. When the car is moving, friction in the air causes this. It is defined as follows:

$$F_{ad} = (1/2)\rho A C_d v^2 \quad \dots(1)$$

Where ρ is the air density, A is the vehicle's frontal area, C_d is the drag coefficient, and v is the vehicle's air speed.

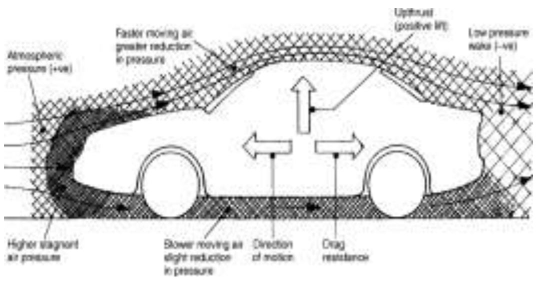

Fig.2. Aerodynamic Drag

1.2 Acceleration force:

When modelling an EV, there are two types of accelerations to consider: linear and angular accelerations. The angular acceleration is expressed as follows:

$$F_{wa} = (IG^2/ n_g r^2)\ a \quad \dots(2)$$

Where I represents inertia, G represents gear ratio, ng represents gear system efficiency, r represents tyre radius, and a represents acceleration. Because the moment of inertia is frequently unknown, we use equation (2) to calculate a ratio to account for angular acceleration. Assuming a 30kW engine with G/r values of 40 and ng of 0.025 kg m^2 with a weight of 800 kg, the result will be a 5 percent less value than the linear acceleration formula to mimic a realistic case. As a result, the formula for the linear acceleration force model is:

$$F_{La} = 1.05ma \quad \dots(3)$$

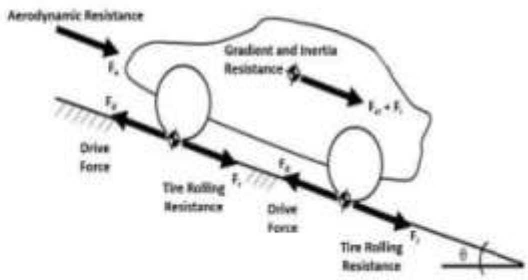

Fig.3. Resistance acting on vehicle

1.3 Rolling resistance force:

The friction between the vehicle's tyres and the road determines this force. As a result, equation (4) is used to simulate it, where the coefficient of rolling resistance, μ_{rr}, is dependent on the tyre type and pressure.

$$F_{rr} = \mu_{rr} mg \quad \dots(4)$$

1.4 Hill climbing force:

The hill climbing force is the final factor to consider in an electric vehicle's dynamics. This force is determined by:

$$F_{hc} = mg\sin(\Psi) \quad \dots(5)$$

The angle of inclination in our proposed model is zero, implying that the hill climbing force has no effect on our model.

1.5 Tractive effect:

Equation (6), which is essentially the sum of all four forces influencing an EV, is used to model the total tractive force. The equation does not include Fhc because it is 0 N.

$$F_{te} = F_{ad} + F_{la} + F_{rr} \quad \dots(6)$$

The energy required to operate the vehicle for each second timeslot is the required output from the

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model's vehicle dynamics. This is the same as tractive power, which is defined as follows:

$P_{te}= F_{te}v$ **…(7)**

This concludes the section on vehicle dynamics models. The power computed in this step to additional factors has the greatest impact on transmission performance.

2. TRANSMISSION PERFORMANCE:

The suggested model's second stage adjusts for mechanical losses. It is concerned with the electric vehicle's motor, taking into account the motor's input and output powers, efficiency, torque, and other factors. It's crucial for determining the battery's energy requirements.

2.1 Motor Power:

The motor transforms electrical energy into mechanical energy. The tractive power can be used to calculate the motor's output power, and thus the torque and electrical power required. While driving, the EV goes through two unique circumstances. The first is when it is driving, and the second is when it is braking and slowing down. The electric power into the motor is more than the output mechanical power when the vehicle is moving and accelerating. When the motor slows down when the brakes are applied, however, the electric power into the motor is reduced. With their respective equations, these two scenarios are summarized as follows:

- EV is being driven; the vehicle is accelerating:
- Output motor power

$P_{motor\ out}=P_{te}/\ n_g$ **...(8)**

- Power into motor

$P_{motor\ in}= P_{motor\ out}/n_m$ **…(9)**

- The vehicle is slowing down due to braking:
- Output motor power

$P_{motor\ out}= P_{te}n_g$ **…(10)**

- Power into motor

$P_{motor\ in}= P_{motor\ out}n_m$ **…(11)**

Electric vehicles can operate in one of two modes: normal forward motion or regenerative braking. In most electric vehicles, a single gear is employed, which means the gear efficiency, denoted by n_g, is constant. Motor efficiency, nm, takes into account both the motor's and controller's efficiency and is determined using equation no (13). The electrical input power required by the motor, $P_{motorin}$, is more than the mechanical power in the case of a vehicle being driven. When the car is braking, however, the motor is employed to slow it down, therefore the electric power is lowered and the mechanical output power, $P_{motorout}$, increases.

To simulate the four aforementioned equations linked to the output and input motor powers, n_g and n, two switches are used. The efficiency of the gear system is constantly taken from the table (1), while the motor efficiency is calculated and modeled in **SECTION 2.3**.

2.2 Motor torque:

Torque is represented by the mechanical output power of the motor divided by angular speed an in equation (12).

$Torque= P_{motorout}/w$ **…(12)**

The angular speed is calculated using equation (13),

$w= Gv/r$ **…(13)**

The velocity is collected from the MATLAB workspace, whereas the gear ratio and tyre radius are constants from Table 1. In radian per second (rad/s), the angular velocity is expressed. To compute and simulate the motor's efficiency, torque and angular speed, as well as numerous losses coefficients, are used.

2.3 Motor and Controller efficiency Modeling:

All the constants are unit-less and are taken from Table No.1. The derivation of the motor efficiency is presented in equation (14):

$\eta= (P_{out}/P_{in}) \times 100\%$

$\eta= (P_{out}/P_{out} + Losses)\times 100\%$ **…(14)**

$\eta=(T_w/T_w+ K_cT^2+K_iw^3 +C)\times 100\%$

Where,

T represents the torque and w represents the angular speed. We employ the torque instead of the current in our proposed model since the current is directly proportional to the torque generated by the motor. Table.1 shows the coefficients of losses for a 100kW induction motor, which is commonly used to model electric vehicles.

3. BATTERY:

Battery models that are accurate are essential for EV modelling. Li-ion battery was used as an efficient battery model in MATLAB Simulink to test the suggested model's reliability. The battery needs are the final stage of the in-hand recommended model. It is determined by the motor's total electric power and the average accessory power. Their addition represents the battery's total power consumption. The accessory power, Pac, can include, for example, the power required by the radio or headlights. Equation (15) demonstrates how to do it.

$$P_{Battery} = P_{motor\ in} + P_{ac} \quad \ldots(15)$$

Results

The general characteristics utilised in the simulation are compared by considering Sedan and SUV Electric vehicles, as well as comparing their drive cycles, such as Indian, American, and European drive cycles.

The parameters are as follows;

A. SUV analysis:

1. For SUV using Indian Drive Cycle: -

- SOC% = 100% → 84.46%

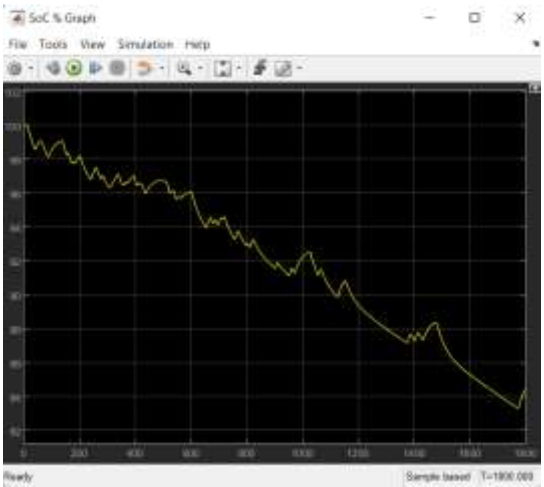

Fig.4. SOC% in Indian Drive Cycle

- Distance travelled= 16.54km

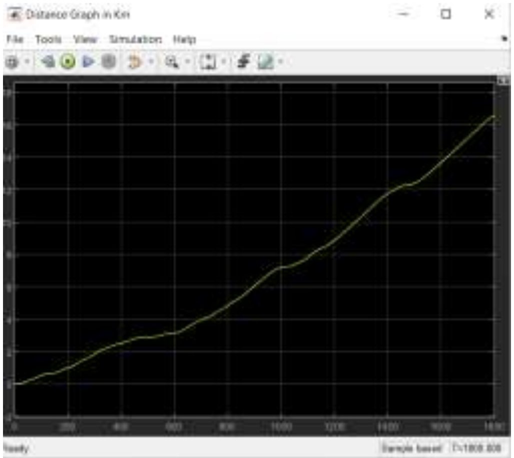

Fig.5. Distance travelled in Indian Drive Cycle

- Average Velocity= 20.29km/hr

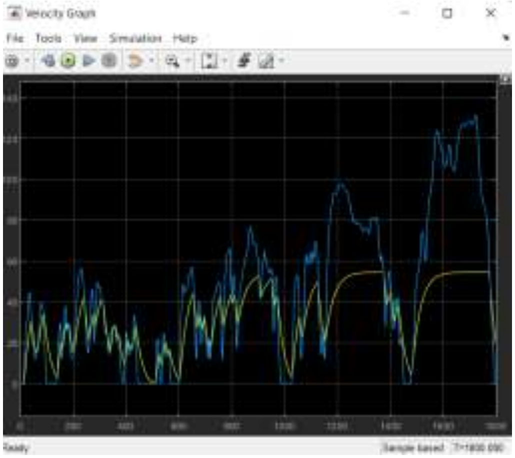

Fig.6. Velocity in Indian drive Cycle

According to figures 4, 5, and 6, the velocity modelled in the Indian Drive Cycle for an SUV is 20.29km/hr; in the Indian Drive Cycle, which has a maximum speed of 90kmph, the vehicle travels 16.54km in 1000sec and the SOC of its battery drops to 84.46 percent from 100 percent. As a result, the car consumes an average voltage of 588V and a current of 143.6A.

2. For SUV using American Drive Cycle: -

- SOC%= 100% → 88.09%

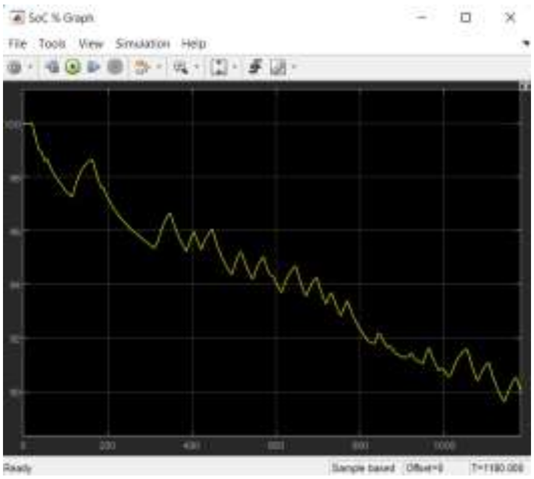

Fig.7. SOC% in American Drive Cycle

- Distance travelled= 8.908km

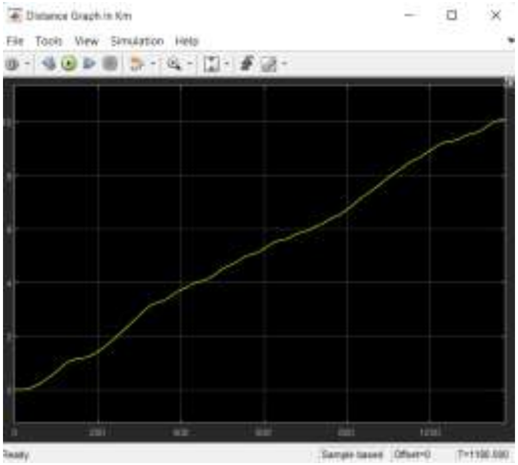

Fig.8. Distance travelled in American Drive Cycle

- Average Velocity= 36.31km/hr

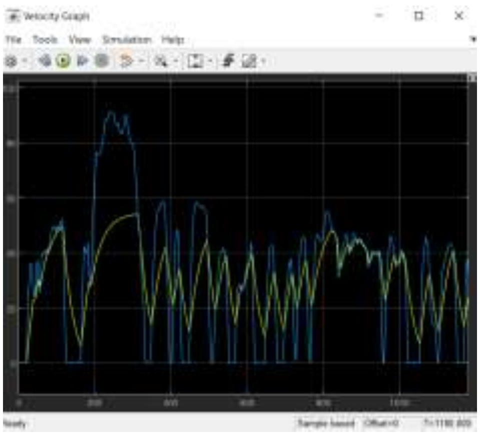

Fig.9. Velocity in American Drive Cycle

In the American Drive Cycle, an SUV's velocity is 36.31 kilometres per hour. According to figures 7, 8, and 9, in the American drive cycle, the vehicle drives 8.908 km in 1000 seconds and the battery's SOC drops to 90.78 percent from 100 percent. As a result, the vehicle uses an average voltage of 558.2V and a current of 106.1A.

3. For SUV using European Drive Cycle: -
SOC%= 100% → 90.33%

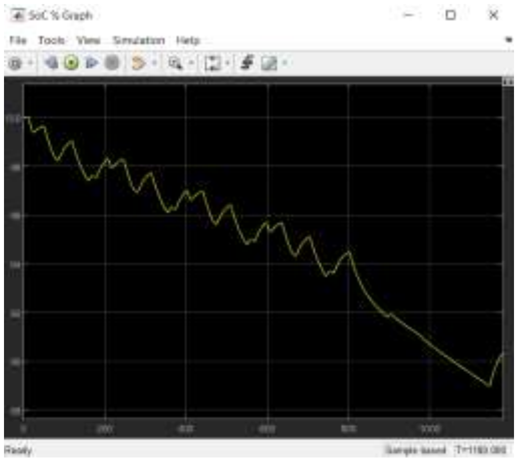

Fig.10. SOC% in European Drive Cycle

- Distance travelled=9.594km

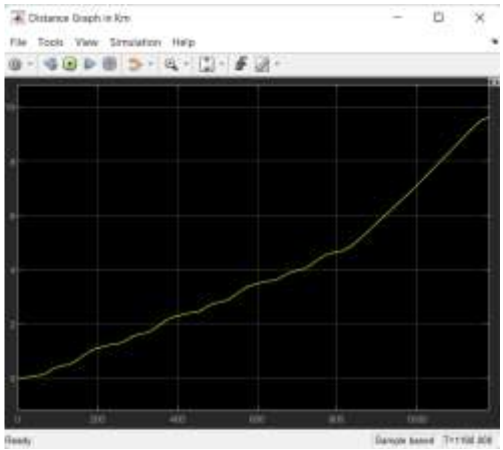

Fig.11. Distance travelled in European Drive Cycle

- Average Velocity= 14.47km/hr

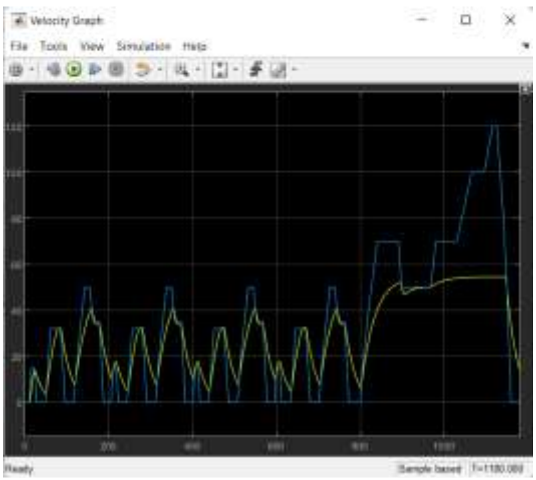

Fig.12. Velocity in European Drive Cycle

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For an SUV, the European Drive Cycle velocity is 14.47 km/hr. In the European drive cycle, the vehicle drives 9.594km in 1000 seconds, and the SOC of its battery drops to 90.33 percent from 100 percent. As a result, the car draws 588.1V average voltage and 102.4A current.

B. Sedan Analysis:

1. For Sedan using Indian Drive Cycle: -

- SOC%= 100% → 80.09%

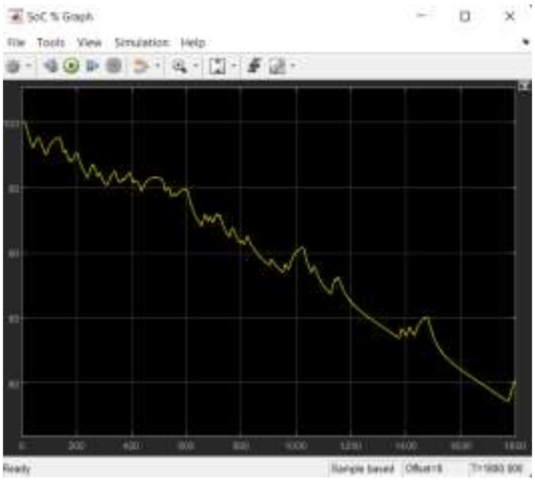

Fig.13. SOC in Indian Drive Cycle

- Distance travelled= 16.13km

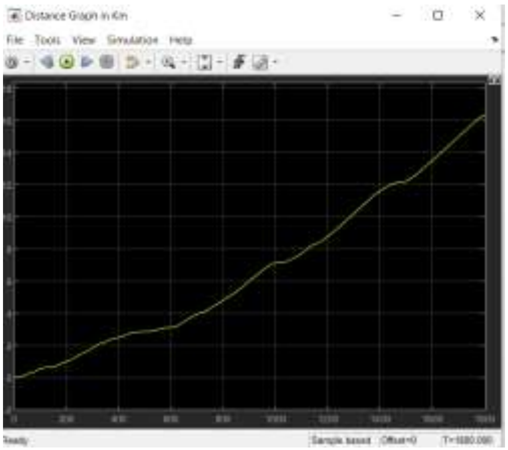

Fig.14. Distance travelled in Indian Cycle

- Average Velocity= 17.93km/hr

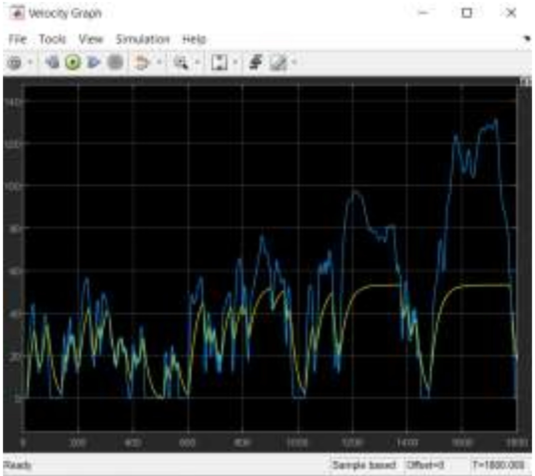

Fig.15. Velocity in Indian Drive Cycle

In the Indian Drive Cycle, the maximum speed for a Sedan is 17.93 km/hr. According to the graphical representations in figures 13, 14, and 15, the car travels 16.13km in 1000 seconds in the Indian drive cycle, and the SOC of its battery drops to 80.09 percent from its initial condition of 100 percent. The car consumes 570.4V of average voltage and 129.4A of current as a result.

2. For Sedan using American Drive Cycle: -

- SOC%= 100% → 88.09%

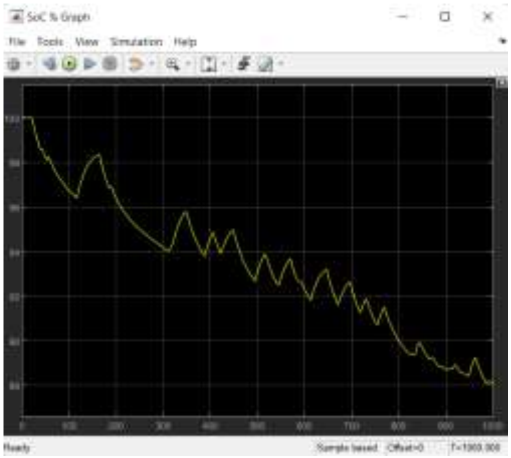

Fig.16. SOC in American Drive Cycle

- Distance travelled= 8.814km

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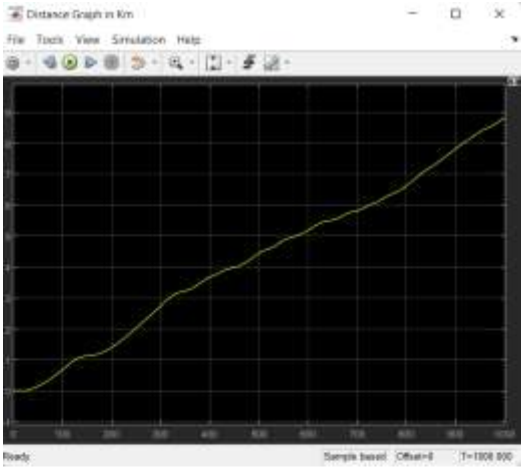

Fig.17. Distance travelled in American Drive Cycle

- Average Velocity= 36.87km/hr

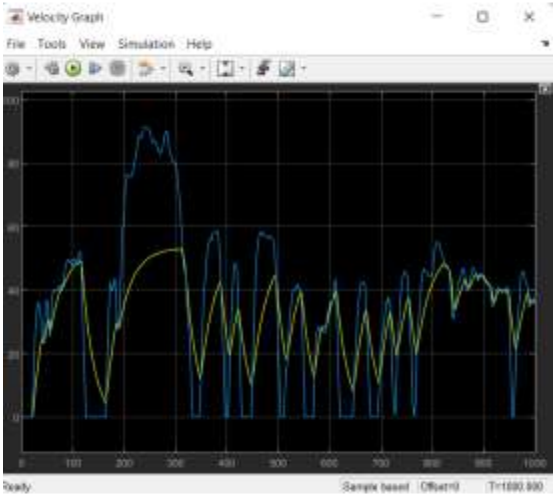

Fig.18. Velocity in American Drive Cycle

In the American Drive Cycle, a Sedan's velocity is 36.27 km/hr. According to the graphical representation in figures 16, 17, and 18, the car travels 8.814km in 1000sec in the American drive cycle, and SOC drops to 88.09 percent from its initial condition of 100%. As a result, the car uses an average voltage of 534.5V and a current of 99.44A.

3. For Sedan using European Drive Cycle: -

- SOC%= 100% → 87.92%

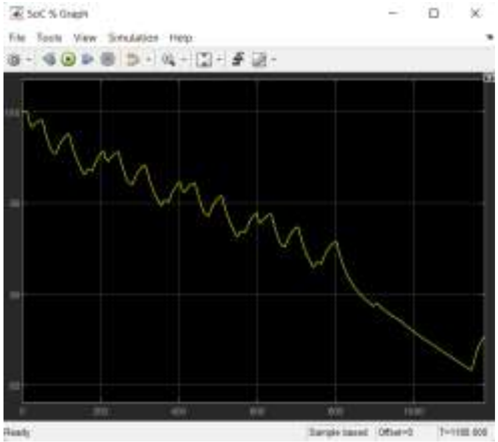

Fig.19. SOC in European Drive Cycle

- Distance travelled=9.478km

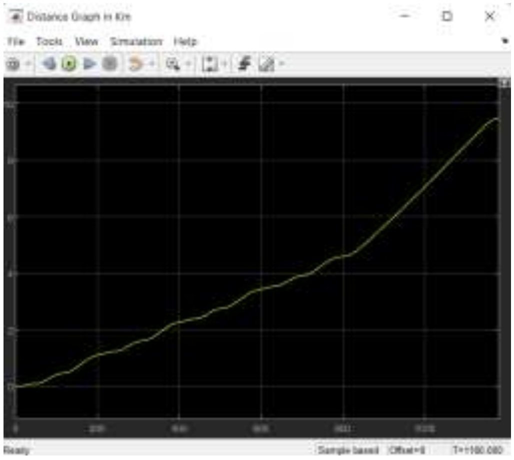

Fig.20. Distance travelled in European Drive Cycle

- Average Velocity= 12.86km/hr

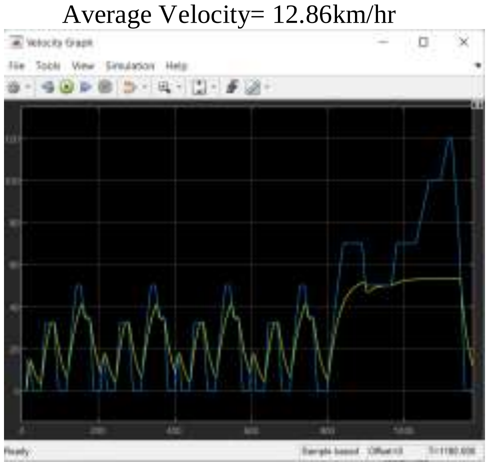

Fig.21. Velocity in European Drive Cycle

In the European Drive Cycle, a sedan's velocity is modeled at 12.86 km/hr. According to the graphical representation in figures 19, 20, and

21, the car drives 9.478km in 1000 seconds in the European Drive Cycle, and SOC drops to 87.92% from 100% in the beginning situation. The car utilizes 55.02A of current and 536.6V of average voltage.

II. CONCLUSION

This paper presented a step-by-step analytical calculation of an EV (electric vehicle). EV was modeled in MATLAB using the analytical calculation. The outcomes of the simulation are summarized. These findings can be used to increase the EV's range. The introduction of this study covered automotive nomenclature and analytical computations. The development of several simulation model blocks such as aerodynamic model, battery model, and motor model was demonstrated using a step-by-step technique based on analytical calculations. For the Worldwide Light Vehicle Test Procedure Cycle (WLTP), New European Drive Cycle (NEDC), and Indian drive cycle (WLTC) inputs, simulation terms in EV range and Battery State of Charge (SOC) were supplied. The implications of various parameters on vehicle performance are then discussed.

REFERENCES

[1] Dhameja, S., 2002, Electric Vehicle Battery Systems, Newnes, United Stated.
[2] Jones, W.D., “Hybrids to the rescue [hybrid electric vehicles]”, IEEE Spectrum, Vol. 40(1), 2003, pp. 70 – 71
[3] Affanni, A.; Bellini, A.; Franceschini, G.; Guglielmi, P.; Tassoni, C., “Battery choice and management for new-generation electric vehicles”, IEEE Trans. on Industrial Electronics, Vol. 52(5), Oct. 2005, pp. 1343 – 1349.
[4] .https://www.researchgate.net/publication/260299 341_Design_and_Development_of_Small_Electric _Vehicle_using_MATLABSimulink.
[5] IEA(2009).Technology Roadmap – Electric Vehicles and plug-in hybrid electric vehicles. Report 2009.
[6] ANDIA REPORT Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide. A Study for the DOE Energy Storage Systems Program, 2010.
[7] International Journal of Advances in Engineering and Management (IJAEM) Volume 2, www.ijaem.net.
[8] International Journal of Computer Applications (0975 – 8887) Volume 24– No.6, June 2011.
[9] Ahmet Onur Kiyakli, Hamit Solmaz, “ Modeling of an Electric Vehicle with MATLAB/Simulink International Journal of Automotive Science and Technology 2 (4): 9-15, 2018.
[10] https://www.intechopen.com/books/new-trendsin-electrical-vehicle-powertrains/model-basedsystem-design-for-electric-vehicle-conversion.
[11] Meradj, M., Cecati, C., Wang, G., and Xur, D., “Dynamic Modeling and Optimal Control for Hybrid Electric Vehicle Drivetrain,” in 2016 IEEE International Conference on Industrial Technology (ICIT), 2016, 1-4, IEEE, Taiwan.
[12] Shukla, A. and Raju, C., “Model Based Designing Approach for Implementation of Hybrid Electric Vehicles Using Matlab/Simulink,” Journal of Advanced Research in Computer Technology & Software Applications 2(1):13- 16, 2018.