SIMULATION BASED STUDY OF ELECTRIC VEHICLE PARAMETERS

BY

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A research paper submitted in fulfilment of the requirement for the degree of Master of Science in Automotive Engineering.

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ABSTRACT

Electric cars play a clear and important role in solving issues related to the phenomenon of global warming, because when they operate, they do not emit any emissions that pollute the environment, and the electrical network can also be used to organize its work. However, there are still significant problems with electric cars that need to be fixed. The main challenges are all related to the battery package of the car. The battery package should contain enough energy in order to have a certain driving range and power capability. The first step in creating a decent electric vehicle model is choosing the right parameters and comprehending their properties. In this research, the electric vehicles are modelled. Three vehicle model is simulated with three different drive cycles. The simulation result demonstrates the significance of each segment parameter to the performance and fuel economy of electric vehicles. All works are performed in MATLAB/Simulink environment.

ملخص البحث

تلعب السيارات الكهربائية دورا واضحا و مهما في حل القضايا المتعلقة في ظاهرة الاحتباس الحراري وذلك لأنها عندما تتحرك لا يصدر منها أي انبعاثات تلوث البيئة وكذلك يمكن استخدام الشبكة الكهربائية في تشغيل محركاتها. ومع ذلك، لا تزال هناك مشاكل كبيرة تتعلق بالسيارات الكهربائية والتي تحتاج إلى إصلاح. وترتبط جميع هذه التحديات الرئيسية بحزمة بطارية السيارة. يجب أن تحتوي حزمة البطارية على طاقة كافية للحصول على نطاق قيادة وقدرة معينة. الخطوة الأولى في إنشاء نموذج لائق للسيارة الكهربائية هي اختيار الملامح الصحيحة وفهم خصائصها. في هذا البحث تم نمذجة السيارة الكهربائية من خلال دراسة ثلاث نماذج من المركبات مع ثلاث نماذج من دورات القيادة. توضح نتيجة الدراسة أهمية كل معامل كل نموذج في أداء السيارات الكهربائية و الاقتصاد في استهلاك الوقود حيث تم تنفيذ جميع هذه الأنشطة البحثية عبر برنامج الماتلاب.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a research paper for the degree of Master of Science in Automotive Engineering.

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LIST OF SYMBOLS

M	vehicle's total mass
f_m	mass conversion factor
F_t	vehicle's overall traction force
$\sum F_r$	overall force of resistance
G	gravitational acceleration force
ρ	air density
V	vehicle speed
V_W	wind speed
A	car's cross-sectional size
CD	aerodynamic drag factor
F_R	Rolling Force
C_{rr}	rolling resistance coefficient
F_C	gradient's Force
θ	angle of inclination
P	power
P_b	power Battery
$\mathrm{U}p_a$	Electrochemical polar voltage
$\mathrm{R}p_a$	Electrochemical polar Resistance
$\mathrm{R}p_C$	Concentration polarization Resistance
$\mathrm{C}p_a$	Electrochemical polarization Capacitance
$\mathrm{C}p_C$	Concentration polarization Capacitance
Q	Battery capacity
E	No-load voltage
E_0	Battery constant voltage
A	Exponential zone amplitude
K	Polarization voltage
V_a	Terminal Voltage
Ra	armature Resistance
La	armature Inductance
Ea	voltage source of back emf
ω_r	Rotor Angular Speed
λ_f	Field-excitation Magnetic Flux Linkage
P	number of magnetic poles
T_{em}	electromechanical Torque
P_{em}	electromechanical power
P	number of magnetic poles
K	constant

LIST OF ABBREVIATIONS

AC	Alternating Current
AMT	Automated Mechanically Transmission
BJT	Bipolar- Junction Transistor
BEV	Battery Electric Vehicle
CVT	Continuously Variable Transmission
DC	Direct Current
EM	Electric Motor
EV	Electric Vehicle
ESS	Energy Storage System
EDV	Electric Drive Vehicle
FCEV	Fuel Cell Electric Vehicle
FTP-75	Federal Test Procedure
GTO	Gate-Turn-Off
Gan	Gallium Nitride
GHG	Green House Gases
HEV	Hybrid Electric vehicle
HWFET	Highway Fuel Test
IM	Induction Machine
ICE	Internal Combustion Engine
IGBT	Isolated Gate Bipolar Transistor
LDG	Longitudinal Drive Generator
Li-ion	Lithium-Ion
MATLAB	Matrix Laboratory
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
NREL	National Renewable Energy Laboratory
NEDC	New European Driving Cycle
Ni-MH	Nickel Metal Hydride
Ni-CAD	Nickel Cadmium
PWM	Pulse Width Modulation
PHEV	Plug - Hybrid Electric Vehicle

PI	Proportional-Integral
PM	Permanent Magnet
PM BLDC	Permanent Magnet Brushless Direct Current
PM BLAC	Permanent Magnet Brushless Alternator Current
PWM	Pulse Width Modulation
R&D	Research and Development
RB	Regenerative Braking
SOC	State-of-Charge
SIT	Static- Induction Transistor
SITH	Static- Induction Transistor Thyristor
SIC	Silicon Carbide
UDDS	Urban Dynamometer Driving Schedule
VVVF	Variable-Voltage Variable-Frequency
VSI	Voltage Source Inverter
WOA	Whale optimization Algorithm
WLTP	Worldwide Light Vehicles Test Procedure

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Electricity-powered vehicles have been used for transportation for more than 150 years. Early 19th research with magnets led to the invention of electric motors, but they weren't employed for transportation till the mid-1800s, when the first passenger vehicles cars, boats, and railroads were equipped with electric motors (or "automobiles"). Several unique fully electric vehicles for personal mobility were produced because of these studies; several of these dominated the auto industry up to World War One. Typically, Thomas Davenport is credited with creating the first real two-person "electric car" in 1847 and the initial real one-person "electric car" in 1834. In 1851, the first electric vehicle (EV) arrived and moved at a speed of around 20 mph (32 km/h), resembling what we may now refer to as a "car." The Edison Cell, a nickel-iron battery that enabled what was already a booming industry, was developed decades later, leading to the release of the first mass-produced electric vehicles. The batteries used during older EVs, and prototypes lacked the storage capacity that the Edison Cell achieved. They could also be recharged, which enabled automakers to design cars that have been useful for middle-class purchasers who can do so at private or public charge infrastructure (several of which were placed in residences with favourable power tariffs or along city roadways). When it came to recreational vehicles, EVs had a sizable market share by 1900. In 1900, just 22% of the 4200 vehicles purchased in the United States were powered by gasoline, and 40% were still steam-powered. Of them, 38% were electric (Bilgin and Sathyan 2014). Compared to internal combustion engine cars of the time, which were unreliable, stinky, and required manual cranking to start, electric cars were relatively dependable and began right away. The thermal efficiency of the engines was very poor in the steam engine vehicle, the second leading contender, and therefore required illumination (Larminie and Lowry 2012) . Between 1890 and 1914, German and American producers and designers shifted their attention to Electric cars and steam - powered to internal combustion engine by creating thermal engines that could power ships, trains, and vehicles in addition to a wide range of other manufacturing and industrial applications. Henry Ford first presented the mass-produced, gasoline-powered Model T in 1908; this event would have a significant impact on the U.S. automotive industry, which relied on ICEs for propulsion. These affordable vehicles were offered for less than one-fourth the cost of current EVs. Petroleum firms actively encouraged local and regional governments to transition to ICE-powered public transportation systems throughout the 1910s, since many early transit systems had been initially electric (Das 2021). When compared to an ICEV, the EV was overly big, costly to operate, and had severe speed and range restrictions. The electric self-starter, created by Ket'ering in 1912, provided the ICEV a definite edge over steam and the EV, and the ICEV quickly grew in popularity. By the end of the 1920s, the once-vibrant EV had been eliminated from American roads. Following this, research activities experienced a substantial increase in the early 1970s (Fan 1994). Electric vehicles were marketed globally towards the end of the 1970s, and research into EVs didn't pick up momentum again until the late 1980s and early 1990s as a consequence of growing oil prices and environmental concerns. This greatly increased the demand for Batteries vehicles in both commercial and personal cars (Hamut, Javani et al. 2016), (Goodarzi 2018). Today’s electric vehicle technology can really be broken. Down into four technologies.

1.2 DIFFERENT TYPES OF ELECTRIC VEHICLE

The four different kinds of electric vehicles fall into the following categories. The first sort of electric vehicle that comes to mind when people think of them is the conventional electric battery vehicle (BEV). An electric engine, a battery that stores electricity, and a control help to compensate the automobile. A battery charging device, which may be mounted at the charging station or transported on board, is commonly used to recharge the batteries utilizing mains electricity and a connector. The controller can normally manage the voltage given to the motor and, as a consequence, the vehicle speed in forward as well as reverse (Larminie and Lowry 2012). During operations, almost no pollutants may be produced. Compared to ICEs' 30% efficiency, EVs may achieve above 90% efficiency (in the battery). They can also use regenerative breaking, which further boosts their efficiency (Hamut, Javani et al. 2016). To enhance fuel economy, the second kind of vehicle, known as a hybrid electric vehicle (HEV), combines the propulsion systems of an electric motor with a gasoline engine. In a HEV, a system for energy storage (ESS) stores electric energy and provides the necessary power for the motor. Comparison to standard cars of the same size, the majority of HEVs employ a smaller engine and a more potent generator. Additionally, since the motor must supply electricity sent instantly to the motor, the battery system requires to have a larger energy capacity. A second energy-saving function of the motor is also present. When the driver reduces the speed of the car, the actions of regenerative braking are activated. In the braking regenerative, the motor produces energy to brake while also producing electricity to replenish the battery system. When travelling in stop-and-go urban traffic, this helps recover a significant amount of the braking energy that would otherwise be lost in a traditional car. The engine uses less gasoline when travelling at moderate speeds and when the vehicle is stopped at a light thanks to the electric propulsion system. The HEV's control technique ensures that the engine only (or mostly) works in its ideal operating area. There still are three different types of hybrid cars: series hybrid, parallel combination, and series-parallel hybrid (Khandaker 2011). The third type, plug-in motor drives, was developed to increase the driving range of HEVs. PHEVs have a battery that can be charged by the electricity grid and an electric motor. When the car's battery is running low, a conventional engine that can refill or replace it can help. PHEVs use less gasoline than HEVs since they get their electricity straight from the grid. However, like any combination, they have the vexing difficulty of locating a mechanic who is educated about both types of engines. The last alternative is Fuel Cell Electric Vehicles (FCEVs), which combine the characteristics of an ICE and a battery to produce energy through an electrochemical reaction. If a power source is provided by hydrogen, which functions as an ICE's source fuel, it can operate continuously (Basu, Tatiya et al. 2019).

1.3 STATEMENT OF THE PROBLEM

Nowadays, the automotive sector and R&D institutions are very interested in electric vehicles (EV), and environmental activists and policymakers see them as one of the most promising technologies to reduce the concentration of greenhouse gases (GHGs) in the ambience and to enhance the supply security of energy in the nations (Young, Wang et al. 2013).When used as a general-purpose passenger or commercial electrical vehicle, EVs have serious drawbacks that discourage utilisation. Regarding top speed, acceleration, range, load carrying capacity, and recharging time, the EV's performance does not match well to those of a regular vehicle. Additionally, the comfort and convenience features that come standard on conventional vehicles are less useful and less readily applicable to EVs (Fan 1994). But there are still serious problems with electric cars that need to be fixed. The three biggest problems are a short driving range, a long charging period, and a premium price. There are three basic difficulties that are all connected to the automobile's battery system. In addition to having enough energy to cover a particular amount of driving distance, the battery package should also be powerful enough to handle accelerations and decelerations (Schaltz and Soylu 2011). However, to the best of the author's information, no work is carried out for simulation-based study of electric vehicle parameters. Thus, in the current study, an effort is made to study the vehicle parameters. We used MATLAB Simulink software to simulate three segments' vehicles and three different drive cycles to select the best-fitted parameters for driving cycle and car.

1.4 RESEARCH OBJECTIVE

Through scientific advancement in batteries, motors, control systems, and other components, the performance of electric vehicles is now being steadily improved. The parts of the EVs must be modelled and matched to analyse and optimise the operating range, power consumption, and other performance indices. To avoid drawing the erroneous assumptions, a strong EV model is essential (Sun 1997).

This research's main contribution is to study and analysis the vehicle parameters to select the best car and driving cycle less energy consumption parameters.

The study aimed to achieve the following objectives:

1- Modelling and simulation of electric vehicle by using MATLAB Simulink software.
2- Three vehicles (with parameters correspond to their segment) and three driving cycles are selected to test the performance and fuel economy of the designed model.
3- To choose the EV that consumes the least energy and performs best.

1.5 RESEARCH SCOPE

After an exhaustive review of previous work on simulation of electric vehicle parameters, it is found that the solutions were based on methods: modelling and simulation. Most of the work has been found in modelling and simulation work. Some studies have been found in testing methods to select the parametric effect on car. The model of EV is discussed and presented. The simulation of three vehicles is done in MATLAB Simulink. The design model's performance and fuel economy are evaluated through the selection of three driving cycles. The optimal design of EVs will be determined by using the best vehicle segment in further research, which is not covered in this research.

1.6 RESEARCH METHODOLOGY

The first stage in creating a successful electric vehicle model is choosing the right parameters for the vehicle and comprehending their properties in order to better understand the elements that influence them. The established EV model is suggested in this study to considerably increase the overall efficiency of EVs and, therefore, the vehicle range. The study investigates vehicle parameters based on simulation of electric vehicles. To achieve the drive system's powertrain goals,

1- A basic EV have modelled by using software Matlab-Simulink.

2- Suggested three segments—Ford Ka 2008, Ford Focus 2007, and BMW 7 Series 2002—will be executed using the four characteristics we chose: weight, radius of the tire, frontage area, and dragging coefficient.

3- Three distinct driving cycles are recommended for vehicle simulation, including (New European Drive Cycle), (Highway Fuel Test), and (Federal Test Procedure). Work as the signal drive.

The overall aim of this research is to look at how different characteristics affect efficiently a vehicle energy and energy consumption.

1.7 DISSERTATION OUTLINE

This dissertation is organized as follows:

- Chapter 1 discovers a detailed historical overview of EV development as well as a quick review of current EV technology. It also gave context and reason for this research.
- Chapter 2 a detailed survey of previous work based on simulation, and modelling of EV approach.
- Chapter 3 Illustrate a block diagram of the EV system, a flow chart of the programme, and a few numerical models for computer simulation of the drivetrain components are included along with background research on the various types of components used in electric vehicles. Electric vehicles, their types, and characteristics are also presented.
- Chapter 4 mentioned the verifies simulated outcomes by analysing results obtained with the simulation or test results from other references, and vehicle simulation is presented with outcome simulation.
- Chapter5 is covered the result and conclusion. With some recommendations of future work.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter literature review attempts to identify performance of the battery, significant factors influencing range and energy usage, and EV performance features. The building of a whole electric engine and the creation of a complete and accurate electric vehicle model are necessitated in order to construct of a purely electric automotive, A pure electric vehicle requires the creation of a cell, power converter, electric motor, sensors, and control system, as illustrated in figure 2.1 When building an electric system, analysis and simulation techniques must be used from the start of the V-cycle to drive the primary selections.

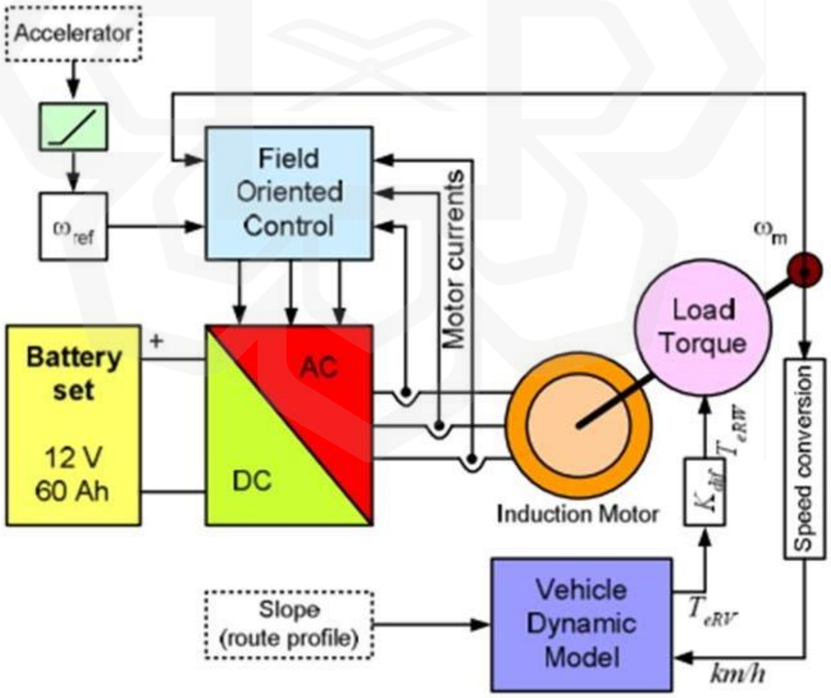


Figure 2.1 Main blocks of the electric vehicle global model (Terras, Neves et al.2010).

2.2 TYPES OF ELECTRIC VEHICLES

EVs might be controlled entirely on electrically or alongside a combustion engine (ICE). A most simple kind of EV that utilizes only employing battery packs as a power supply. These are classified as hybridization electric cars. Automobile employing two or more fuel sources, store devices, or converters should be considered HEVs when at minimum one of them produces electrical energy, according to a proposal made by Technical Committee 69 of the International Electrotechnical Commission (Electric Roads Vehicles). This definition allows for a wide range of HEV combinations, such as ICE with battery, and flywheel combine with energy source as well as capacitor with battery, and fuel cell, and so on. Consequently, as shown in Fig. 2.2, both the citizens and professionals have begun to refer to cars with an ICE and an electric motor as HEVs, cars with such a battery and a capacitor as ultra-capacitor facilitated EVs, and cars with a battery and a hydrogen fuel. Given the widespread use of these terminology, the following categories can be used to group EVs (Un-Noor, Padmanaban et al. 2017).

1. Hybrid Electric Vehicle (HEV)
2. Plug-in Hybrid Electric Vehicle (PHEV)
3. Fuel Cell Electric Vehicle (FCEV)
4. Battery Electric Vehicle (BEV).

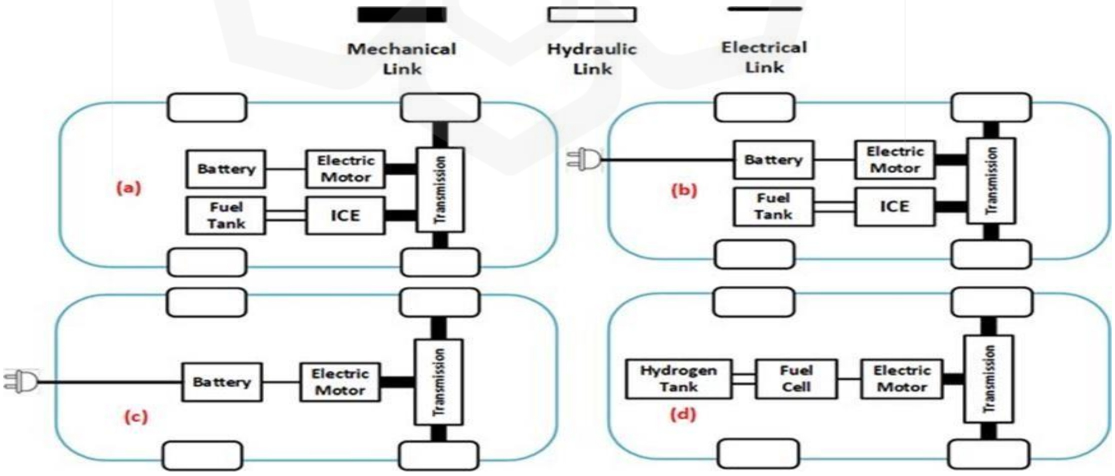


Figure 2.2 basic principles of various vehicles (Morsy, José Pablo et al. 2020).

2.2.1 Hybrid Electric Vehicle (HEV)

Dual energy sources are used to drive hybrid electric cars (HEVs). Current power sources include combustion engine (IC) engines that run on petrol or diesel fuel and chemical storage systems that are powered by electric motors. High engine performance in HEVs, such as sudden movement, is produced by the electrical drive system's great maximum output and quick power action. The fuel economy and pollutants of IC engine-powered cars are drastically enhanced by the use of too few internal combustion engines with optimized operating points and energy recovery. Good consumption of fuel of petroleum, coupled with simple fuel supply systems, results in a long range of operation and easy replenishment. All these benefits combine to produce HEVs the most promising alternative for next-generation vehicles (Ehsani, Gao et al. 2007). Based on the drivetrain structure, HEVs can be further classified into four types as follows:

- Series Hybrids,
- Parallel Hybrids,
- Series–Parallel Hybrids, And
- Complex Hybrids.

A HEV possesses wider range than a BEV, it also comes with certain disadvantages, such the fact that it costs more to operate than a BEV and that it may be charged at home (Basu, Tatiya et al. 2019).

2.2.2 Plug-In Hybrid Electric Vehicle (PHEV)

The Plug-In HEV was typically developed to extend including all speed range of HEVs. However, the difference is that PHEVs use electric engine as their primary source of propulsion, necessitating massive storage capacities than HEVs. Whenever the power gets low, PHEVs called mostly on ICE for a boost or to launch the battery pack's charging, PHEVs commence off in an "all electric" mode and run-on energy. In this case, the ICE should be used to broaden the scope. While PHEVs can use rechargeable batteries, HEVs cannot instantly quit using grid power to charge their batteries. Due to their tendency to run entirely on electricity, PHEVs frequently have less of a negative environmental impact than HEVs. Vehicles also use a minimal amount of gasoline, which reduces the overall cost. This may appear to really be relatively popular on the auto market, as seen by sales of the Toyota Prius and Chevrolet Volt (Sen 2010).

2.2.3 Fuel Cell Electric Vehicle (FCEV)

Fuel Cell Vehicles would be another name for FCEVs. The term for these cars originates on their core component, fuel cells, which produce power through biochemical reactions. The term "hydrogen fuel cell vehicles" is frequently used to describe FCVs since hydrogen is the main source of power for these types of bonds.' In primarily in high containers, FCVs carry hydrogen; Oxygen that it takes coming from external air, is also an element of the electricity generating process. The wheels are propelled by an electric motor that is powered by power generated by the fuel cells. Batteries and supercapacitors are two types of energy storage devices. In frequently manufactured FCVs like the Toyota Mirai and Honda Clarity, batteries are employed. As a by-product of the power production process in FCVs, water is naturally expelled from vehicle through the exhausts. During fuel cell technology, electricity is really generated by the combination of oxygen from the atmosphere and hydrogen from the tanks, which propels the motor. As a by-product, just water is obtained and discharged into the atmosphere. It really can lessen its environmental effect greater than any other EV because it emits no carbon. Another great benefit—and by far the most important one at the moment is that refuelling such cars needs about the same length of time as filling up a traditional car at a service station. The consequences as, the advent of such cars is becoming more likely to happen soon (Sen 2010).

2.2.4 Battery Electric Vehicle (BEV)

BEVs are fully electric cars that draw all their power from batteries; they complete absence the conventional combustion engine and should be charged up by having to plug into an external power supply. The current battery ability has a direct effect on the BEV's scope.

A BEV could indeed normally travel 100–250 kilometres on a single battery charge. Bigger BEV models are available, but they command a heavy amount since they are luxury vehicles with high starting prices. BEVs, similar to any other electric car, can charge up their batteries through regenerative braking, which tends to slow the car down using the motor and recovers a few energies that is transformed to heat BEVs have the benefits of becoming simple to build, simple to operate, and smooth. It also is eco sustainable because it releases no greenhouse gas emissions. The main drawback is the limited distance for every charging, but when you consider some other benefits, it usually makes for such an excellent choice for urban families.

Table 2.1 Analysing Specific Benefits of Different Electric Kinds Of vehicles (Basu, Tatiya et al. 2019).

EV sort	Driving component	Energy source and infrastructure	Key features	Drawbacks
BCV	Electric motor	Battery and ultracapacitor	• no emissions • Limited range • Self-sufficient of crude oil • Available to purchase	• Range • Capability of the battery • Reusable batteries
HCV	Electric motor and ICE	Battery, ultracapacitor and ICE	• So little emissions • Wide operating range • Depends on oil • Complicated architecture of transmissions • Easily obtainable in stores	• control over energy resources • Battery capacity

FCEV	Electric motor	Fuel cell	• Significantly lower pollution • Extreme energy effectiveness • Not depending on crude oil • Currently expensive • Unrelated to the provision of power • Being developed	• The expense of fuel cells is expensive • Possibility of producing hydrogen • Absence of fuelling infrastructure

2.3 MODELLING PARAMETERS WITH MATLAB/SIMULINK

Maintaining prototype or modelling libraries, as well as systems/subsystems in MATLAB Simulink, is critical since they may be utilized for development, detail design, or several predictions all through the car creative process. (Oral Vatan. 2011), is used MATLAB/Simulink to model electric vehicle. The battery in the model is 30 kWh. This car consumes 0.58 kWh/100km in the city as well as 0.44 kWh/100km outside the town. The car's maximum distance is 52-70 kilometers. (Kıyaklı, A. O., & Solmaz, H. 2019), created an electric drive dynamic model in MATLAB/Simulink. Car electricity demand and range are calculated using simulation using NEDC and WLTP cycles in the paper. In addition, the method computes the electricity conserved by regenerative braking (RB), which in this work saved 11.73 percent in the ECE-R15 cycle, 5.87 percent in the EUDC cycle, 8.06 percent in the NEDC cycle, and 7.47 percent in the WLTP cycle, increasing the total energy savings of EVs.

(Moldovanu, D. 2020), MATLAB was used to implement of a simple electric car, including aerodynamics, the electric motor (executed using a transient response), calculate the top velocity speed of an automobile using the total of relevant loads, and the model's verification. (Abulifa et al 2018), provides a MATLAB-Simulink model for integrating the overall structure with BEV elements Furthermore, The Battery electric automotive model and formulas were evaluated using MATLAB-Simulink. Proton

IRIZ, a Malaysian automotive vehicle standard, is utilized in the model to assess battery voltage, current, power, and state of charge, that are all key parts of an EV.

(T.A.T. Mohd1. 2015), gives a simulation environment of a 100 % electric car was used the Matlab-Simulink method to explore load demand throughout driving, regeneration, and drive performance to figure out the best energy control approach and exact component size, in addition to restrict usage of energy. The study concentrates at drivetrain components for example a drive system, a lithium-ion battery, a voltage regulator, and a battery controller, have described mathematically. (Urazel, B., & Keskin, K. 2020), fully electric vehicle (EDV) developed and modelled in MATLAB/Simulink with three separate driving conditions, namely: Urban Dynamometer Driving Schedule, The New European Driving Cycle and National Renewable Energy Laboratory Class-3. Newton's law, which accounts for slope, rolling and aerodynamic resistances, and pulling power, is used to represent EDV motion. The figures obtained for battery power requirements match to the specific speed of the specified driving cycle. The proposed architecture can handle waste energy for EDV, in which the motor functions as a power source and charging the battery.

(Sharmila et al. 2021), EV regenerative braking, a power converter developed utilizing an H-bridge is used. The vehicle's energy released is collected by slowing the electric engine while in reverse mode. The research utilizes a low-run-time electric car that is simulated in MATLAB utilizing simscape elements. To accomplish the desired velocity, electric cars use a PI controller. Zhou et al. (2014), uses Matlab/Simulink and the Sim Power System/Sim Drivetrain package to create a dynamic simulation model of a battery-powered car. The Electric car model includes a flexible framework that allows for simulation at various accuracy degrees. This feature will unify simulation models connected with controller deployment and testing on a unified system. A high load application, like a public bus, required the development of an automated mechanically gearbox (AMT) model and its controller.

(Lee et al. 1997), Model the whole system of the EV, which includes a battery pack, driving system, and load condition, with the goal of seeing how the variation in battery voltage affects the output torque of the motor. The knowledge that the voltage output fluctuates throughout driving will assist in the selection of voltage supply and the design of EV electrical power equipment. (Slough et al. 2021), a tool for evaluating the performance of electric vehicles having various motors, chassis styles, and storage capacity to assist consumers in selecting electricity. This study examines the features of the electric vehicle versions of both the Tesla Type S 100D and BMW i3. The Simulink and Simscape modelling and simulation tools in MATLAB take into consideration factors such as system voltage, motor design, and physical vehicle composition, related to the motor, drive train, and chassis. The test items include virtual vehicle structures, speed control, motor drivers, and sequences of driving citations. In almost every aspect, the Model S performed better than the i3.

(Kaushik, S. 2019), seeks to just provide steady acceleration and torque in electric vehicles, therefore an improved regulator, such as the Metaheuristic WOA (Whale Optimization Algorithm), delivers more precise EV wheel drive in typical operating mode operations Scientists use modelling and simulation in MATLAB/Simulink to handle the major difficulty of drivetrain components layout with the aid of Ac induction motors. (Terras et al 2010), Sub-model two studies utilizing MATLAB/Simulink can be beneficial in analyzing the dynamic behavior, autonomy, and power consumptions of electric commercial vehicles such as the Fiat Seicento Elettra. The system can execute conventional fully electric driving tests including launching, braking, accelerating, and decelerating. When the simulation findings are compared to the data given by the automotive manufacturer, (Terras et al 2010), It is possible to assert that there is a high degree of resemblance between the predicted dynamics and power consumption and those attained through simulation. (Sarathkumar et al .2020) a simulation of an electric car drive using (Society of Automotive Engineers), a Japanese driving cycle, and (Extra Urban Driving Cycle), a European driving cycle, as incoming signal. The model could be employed to analyze the energy flow and capabilities of the electric drive for various driving cycles. However, (Babangida, A., & Szemes, P. T. 2021), create modeling and analysis of a small commercial vehicle powered by an electric motor based also on Permanent magnet synchronous motor of a 2020 VW Crafter. The study took into account a whole automobile model with seven degrees of freedom (DOF). The study discovered that switching petrol cars operated by ICEs with electric vehicles reduced fuel usage by a substantial amount. The work reported by (Husain, I., & Islam, M. S. (1999), switching reluctance magnet (SRM) drive design of a fully electric powertrain. Due to its high density of power and good motor-load torque-speed coupling properties, SRM is employed. The author provides a MATLAB-Simulink-based system level simulation tool for electric automobiles. SRMs were shown to be capable of working over a large speed range in the constant power zone. This characteristic, combined with other advantages of SRMs, makes it excellent for use in electric vehicles. Also, (Vempalli, S. K., Ramprabhakar, J., Shankar, S., & Prabhakar, G. 2018), concentrate on a step-by-step design approach for estimating the ratings of various components in an electric vehicle driven by a vector-controlled induction machine. To boost modelling performance, a physical modelling technique was employed for car design. MATLAB/Simulink and the Sim Power System/Sim Driveline tools are used to create and simulate a dynamic model of an electric car with energy recovery capability. The simulation model output shows battery charge during regenerative braking and vehicle increasing speed ranging from 0 to 60 km/h. To conduct research on power flow in both regeneration and driving (Kasoju bharath kumar.2020) utilities software MATLAB/Simulink to simulate basic electric vehicle motor-drive system. The simulation model calculates the flow of energy and performance of an electric drive under certain speed and torque load circumstances. (Maaz et al. 2018) evaluations were made of the EV's performance and range for drive periods like FUD, SFUDS, Class 1 and Class 2 WLTP cycles, various ranging conditions have indeed been modeled and verified. The power supply for connected equipment to (EVs), as determined by the analysis, has a considerable impact on deciding the distances traveled. Making the right choice can help to increase the rechargeable vehicular' capacity. The effectiveness, gravity, expense, cooling, top acceleration, fault-tolerance, protection, and stability of switched reluctance drive system, induction motor, permanent magnet blushless dc motor, and brushed dc motor drives are compared in selecting the most suitable electric motor drives for vehicle applications. According to research, switching reluctant motor drivers are the preferred choice for electric cars. (Xue et al. 2008), in their research, employ six different types of electric motor drivetrain systems for EVs. Moreover, pick the ideal electric engine run for electric vehicle applications, a comprehensive review of the importance of EVs in drive systems and their own performance, body mass, end up paying, temperature, cruising speed, flexibility, safeness, and efficiency is derived on switched reluctance motors, induction motors, permanent magnet brushless and brushed DC motor drives. The findings of the study, switching reluctance motor drives are the top choice for powered mobility. To determine the optimal EV setup based on necessary power and transmissible pulling torque. (Eckert, J. J., Silva, L. C. A., Costa, E. S., Santiciolli, F. M., Dedini, F. G., & Corrêa, F. C. 2017), Perform a detailed examination of an ideal multi-cycle propulsion layout for only a plug-in electric truck. The research looks at four distinct drive system combinations using in-wheel motors and differentials. Determine electric motor (EM) torque curves and powertrain transmission ratios using genetic algorithm-based optimization techniques to improve vehicle range and performance. Battery discharges are reduced in the study over the following driving cycles: The FTP-75, HWFET, and US06 are used to distribute the vehicle power requirements among the drivetrains depending on the energy regulation optimization technique.

2.4 MODELING POWER TRAIN

(Hofman, T., & Dai, C. H. 2010), evaluation of the effects of different transmissions on energy use Using a fixed gearbox, a conventional powertrain, and subsequently a CVT gearbox, the powertrain system was evaluated.

Table 2.2 The Relationship between Different Transmission systems and Energy Demand Waste of energy (kWh)

Gearbox Type	**NEDC**	**FTP75**
Constant Gearing	1.58	2.81
Manual	1.62	3.31
CVT	1.59	3.14

However, battery automobiles have a restricted driving range and inadequate battery pack energy. Since battery-powered vehicles have restricted ability to store energy, Thermal efficiency and important power generation are considered to be important. Methods that may be used in an EV to increase energy efficiency and enhance electric engine performance (Fadul, et al 2018). Research on vehicle characteristics focused on mathematical modelling of an electric car's dynamics when combined with an induction motor powered by Li-ion batteries is presented. This research makes use of MATLAB/Simulink. A study of on-board to wheels energy transfer comes from the work's simulation of an electric drivetrain. An analysis reveals that vehicle torque and speed correspond with an acceleration index for electric vehicles.

2.5 BATTERY MODELING OF ELECTRIC VEHICLE

The most common electricity energy source used in electric vehicles is batteries. It's crucial to comprehend how an electric vehicle's battery reacts and works during treatment cycles. An accurate estimate of a battery with a particular application is necessary for an efficient assessment and modeling. As a result, numerous models in the field of battery modelling have been presented (Mousavi G., S. M., & Nikdel, M. 2014). Electric vehicle sectors are becoming more appealing due to their ability to minimize greenhouse gas emissions and dependency on oil. The key to this massive transition for automakers will be lithium-ion batteries (Yenigala, T.2017). The operation of a rechargeable battery for various charge and drain rates, output current characteristics related to various temps, and automobile loading cycling will be studied using a muti computer simulation model.

(Janiaud, et al 2010), provide a MATLAB-Simulink-based framework for modeling electric powertrains to optimize individual and drivetrain effectiveness (strongly related to automotive capacity). Based on its features and driving cycles, this framework is used to decide the battery storage (lithium-ion, nickel-cadmium), capacities, and size. (Campagana et al. 2020), attempts to discover three simple battery models that may be used for early-stage Development and modeling of a battery-operated system. The paper compares three alternative parameter identification and modelling methodologies. Models examined include the Thevenin, Rint, and modified Shepherd models. The parameter estimation processes were done to the LG 18650HG2 battery cell in a methodical manner. Thevenin model, whose values were verified by practical studies, had the best results, according to an examination using the other models. Currently, lithium-ion cells have become the greatest popular EV packs available. (Vidyanandan, K. V. 2019), Examines the battery of choice the restriction of lithium-ion batteries in EVs is not encouraging. The primary reason for this is because the present electrode materials used in Li-ion batteries have reached their performance limits.

2.6 MOTOR MODELING FOR EV

Throughout this work, several electric motors are examined and contrasted in order to discover the merits of this motors and the finest one to be used in electric car operations. Straight current, inductive, permanent magnetic sync, switching reluctance, and brushless DC motors are the key five sorts of electrified motors examined.

(Hashemnia et al. 2018), he analyzes the performance of various motors and concludes that, although though induced drive science is far greater advanced than those of another motors, brushless DC and permanent magnet motors are more appropriate for EV applications. By using such motors, waste would be decreased, less gasoline can be used, and the power-to-volume relationship should increase. The cost of persistent magnetism metals is decreasing, and stable magnet and brushless DC motors are highly efficient, making them increasingly desirable for EV applications. (Hadboul et al 2021), induction machine (IM) electric motors are utilised as the primary drive for EVs. The MITSUBISHI I-MIEV model city automobile is modelled and simulated using MATLAB/Simulink. A thorough (EV+IM) modelling was used to evaluate several case scenarios with different speeds and loads. The simulations experiments demonstrate that IM is adept of regulating the EV in a variety of movement modes with high stability.

2.7 SUMMARY

Electric Vehicles (EV), which are battery-powered, have been advocated in the literature among the mentioned answers since seem to be effective, silent, emit zero emissions, and may be controlled by the manager of the electricity grid. The primary obstacles with EV include battery-related concerns, high starting costs, restricted driving range, and prolonged recharging period. Battery needs to have enough ability to move a specific range of deliver adequate angular velocity output.

CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION

To ensure the lowest possible use of stored energy, the parts of a driving system must match. Therefore, an in-depth knowledge of the vehicle's energy needs, and the features of the propulsion train's component pieces is essential. The vehicle and propulsion system component specifications were established based on the performance objectives and are discussed in the following sections.

3.1.1 Battery Types

A very important part of the BEV powertrain is the battery. According to the needs of the driver, it gives the traction motor the required amount of electric power. The battery should be able to store a significant quantity of electricity and should also be extremely efficient, able to handle higher electrical discharge, take energy generated efficiently, get a long cycle life and calendar life, and be capable of damage. Additionally, it ought to comply with all temperature and safety requirements. Even though numerous other kinds of energy battery technologies are being developed, batteries are now the main electric power source in all BEVs. The three most popular battery types being used in contemporary automobiles will be the main topic of this study.

- Lead-Acid Battery, (PBAC)
- Nickel Metal Hydride Battery (NIMH),
- Lithium-Ion Battery (LI-ION) (Sen 2010).

3.1.1.1 Lead Storage Battery

The most well-known and frequently used kind of battery for electric cars is the acid batter. As seen in figure 3.1. Since IC engine cars frequently use lead batteries, these batteries are well recognised. However, stronger acid batteries that can endure severe cycling and employ a gel electrolyte rather than a liquid electrolyte are used for electric cars. The cost to make these batteries is higher. Lead acid batteries' primary reaction is: (Hamut, Javani et al. 2016).

$$\mathbf{Pb + Pb02 + H2S04 = 2PbS04 + 2H20}$$

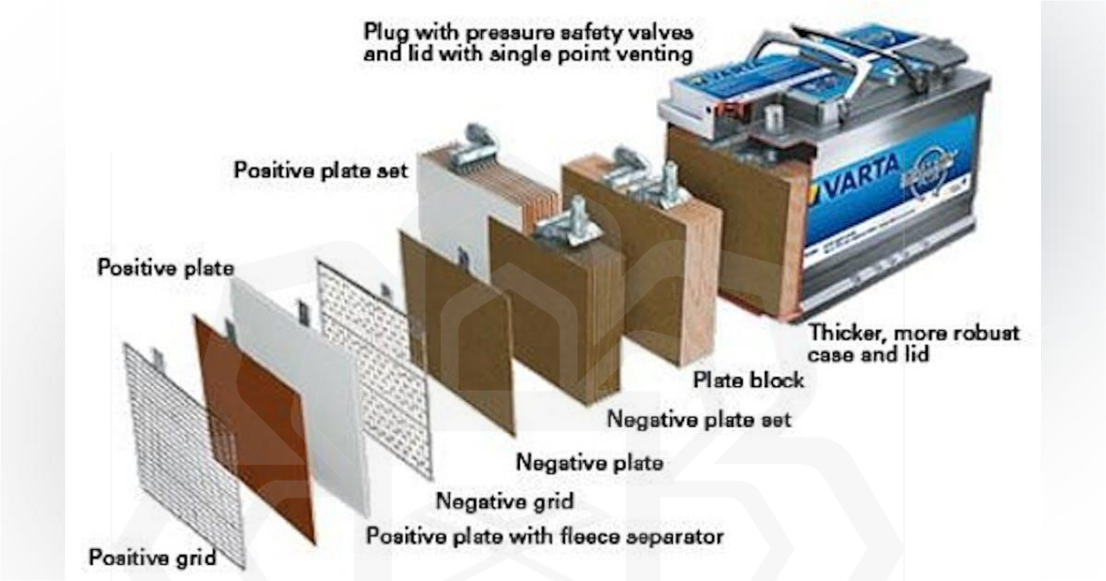


Figure 3.1 Simple Lead-acid battery (Scrosati, Garche et al. 2015).

3.1.1.2 Nickel-Metal Hydride

The nickel-cadmium (NiCad) cell, which was previously widely used, is comparable to the NiMH cell. However, in addition to being costly and hazardous, cadmium also causes cancer. The metal hydride makes it possible to employ hydrogen and substitute cadmium in the NiCad cell's anode. A compound in which the metal is joined to hydrogen is known as a metal hydride. Common materials like nickel and cobalt are mixed with lesser amounts of other elements, but the precise composition of the metals is often private. Similar to NiCad, the NiMH cell has a nominal voltage of roughly 1.2

V. Regarding nickel-cadmium cells providing a number of advantages, and other chemistries, In contrast to these, NiMH has a very high self-discharge. Batteries made of NiMH and NiCad may have "memory" effects. The capacity loss brought on by numerous partial charges is known as the memory effect. Like lead-acid batteries, these battery cells require frequent equalisation to make sure that all of the cells in a battery pack are charged similarly (Goodarzi 2018).

3.1.1.3 Li-ion Battery

The Li-ion battery operates on the premise that, during discharge and charge, lithium ions swing between the Cathode and Anode electrodes in the electrolyte. Cobalt, nickel, and manganese-based kinds are among the most developed ones. The greatest cell voltage (3.7 V), most specific energy (90-160 Wh/kg), highest specific power (250-450 W/kg), and reasonably long cycle life are their main features (1200–2000 cycles). The iron phosphate-based, nickel manganese cobalt-based, and titanate-based kinds are recent developments with the goals of a safe design, greater longer service lifetimes and higher battery power. The Li-ion battery still has the disadvantage of being expensive (600–1000 US$/kWh). Graphite serves as the anode while Provision of lithium-based transition metal oxides as the cathode in li-ion batteries. Chemical processes involving lithium ions are (Sen 2010&Wang, Liu et al. 2014).

$$\mathrm{LiMnO_2} \leftrightarrow \mathrm{Li}_{1-\mathrm{x}}\,\mathrm{M_n}\,2\mathrm{O_4} + \mathrm{xLi}_+ + \mathrm{xe}_-$$

$$\mathrm{C} + xLi_+ + xe_- \leftrightarrow Li\mathrm{+x\,C}$$

$$\mathrm{LiMn_2O_4} + C \leftrightarrow \mathrm{xLi\,C} + \mathrm{Li}_{1-\mathrm{x}}\,M_{n2}\,O_4$$

Results from comparing the specific power, specific energy density, and cycle life of several battery types are displayed in the table 3.1.

Table 3.1 Performance Analysis of Several Battery Kinds (Wang, Liu et al. 2014).

Types of battery	Specific energy（Wh/kg）	Specific Power(w/kg)	Energy density（Wh/L）	Cycle life
Lead-acid battery	35	130	90	500
Nickel cadmium battery	55	170	94	500
Nickel metal hydride battery	80	225	143	1000
Lithium-ion battery	120	180	360	1200
Lithium iron phosphate battery	120	90	10	2000
Fuel battery	500	60	/	/

3.1.1.4 Performance Comparison of Different Types of Battery

According to the tables, lithium-ion cells are chosen to be used in electric car batteries since they offer a high specific energy, a long battery life than lead-acid, nickel-cadmium, and nickel-metal hydride batteries, and a greater energy density than lithium iron phosphate batteries.

3.1.2 Motor Type

The heart of an electric car is the propulsion system, and at its heart is the electric motor. The motor transforms electrical generated by the battery into mechanical motion to propel the automobile. It serves as a producer to send energy back to such energy source while it is engaged in regen activities. EVs can still have various numbers of motors, based on their requirements. The Toyota Prius alone has one motor, but the Acura NSX might have three. The choice is made regardless of the type of vehicle and the task for which it was designed. EV drives should have high torque and power densities, excellent effectiveness over a vast scope of torques, great operability, high reliability, and few maintenance needs in order to work efficiently. There are many various kinds of electric machines, but four basic motor types are used in EV drives: brushless DC, induction, switching reluctance (SR), and permanent magnet (PM) motors. They have various topologies, as seen in Fig. 3.2 (Chau 2014).

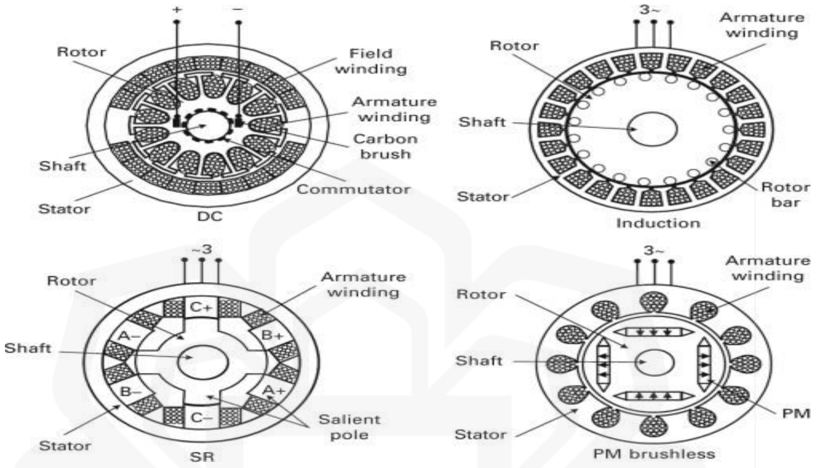


Figure 3.2 Existing EV drive topologies (Chau 2014).

3.1.2.1 DC Motor

In the past, DC drives for EVs were often employed. The whole family includes the independently excited DC, shunt DC, series DC, and PM DC kinds, it may be identified through the use of PM activation, the mutual connection of the fields and the armature windings, or both. Because commutators and brushes are used, all DC drives have a flaw. Brushes are in charge of friction and radio frequency interference, while commutators limit the speed of motor and produce waves in the torque. Additionally, Commutators and brushes ought to be serviced on a regular basis as a result of daily use. They are less dependable and inappropriate for maintenance-free operation because of these flaws. The maturity and simplicity of DC drives are their main benefits. Unfortunately, due to their relatively low performance and high maintenance expenses, DC motors are not typically preferred with modern EVs.

3.1.2.2 Induction Drives

The fact that IM has been employed so frequently in motors for traction is likely due to its essential qualities and excellent dynamic performance. The fixed Power rate (CPSR) of the induction motors is restricted by the pullout torque, however, it can reach up to 5, which is crucial for traction applications. The application may find the straightforward structure and thus minimal cost to be appealing. When compared to PM machines, IM requires more both weight and volume for the identical power rating. Additionally, induction motors have large losses, a poor power factor, and poor efficiency. The motor slip, which is related to rotor frequency and voltage, determines how much copper is lost in the IM rotor (Salameh 2020).

3.1.2.3 Switched Reluctance (SR) Drives

During the condition of torque, a switching reluctance motor (SRM), a form of stepper motor, is operated. In contrast to other DC motors, the destructive power is given to the stator, which is larger than the rotor. Since the electrical architecture of a motor is quite complex, it does not require electricity to move any parts mechanically. Instead, switching systems are used to transfer power to the moving parts. Here, the SRM configurations are precisely provided by electronic devices, and switching time is a component of torque ripple. By creating new controllers, the torque ripples can be reduced. When the load is moved to the coils and the current flow synchronizes, allowing the generator to operate at a higher speed than the typical kind of motor. The generator and the motor are operated by the prime mover. SRM names the DC motor, which is wounded in the coils. There are actually no windings in the rotor, therefore all of these solely apply to the stator portion. The type of rotor is salient pole and it is formed by the substance of soft magnetic. When the magnetic reluctance creates an impact on the rotors, the poles of the rotor are aligned to the stator poles, and the power is then applied to the stator windings. (Eldho Aliasand and Josh 2020).

3.1.2.4 Permanent Magnet (PM) Brushless Drives

The motor's stator receives electricity from a DC power source through an inverter, and the rotor is constructed of PM (most frequently NdFeB). It's more effective than induction motors due to the fact that there are no windings in the rotor, preventing rotor copper loss. Additionally, this motor has a better torque density and specific power as well as being lighter, smaller, more dependable, and more efficient at dissipating heat (which is produced in the stator). Its limited field-weakening capability, however, results in a rather small constant power range. Due to the back EMF produced in the stator windings, the torque likewise decreases as the speed rises. Costs are also increased by the use of PM. However, more field windings could increase the speed spectrum and improve overall efficiency. Because both PM and field windings are present, these configurations are frequently referred to as PM hybrid motors. However, the complexity of the construction places limitations on such setups, and the speed ratio is insufficient for EV use, particularly in off-roaders. (Un-Noor, Padmanaban et al. 2017).

3.1.2.5 Comparative of Current EV Motors

The aforementioned drives are assessed for their appropriateness for usage in EVs in regard to power output, efficiency, stability, reliability, ripeness, cost level, noise level, and necessary maintenance. With 1 being the worst and 5 being the greatest, a point system is used to grade assignments. According to Table 3.3, The SR motor’s high voiced noise level is its principal disadvantage, while the major benefit of the SR drive is the requirement for routine maintenance. The major benefit of induced driving is that it's the least expensive, but the main advantages of PM brushless drives seem to be their amazing performance and huge power density. According to the research, two drives that appeal to consumers that most are induction and PM brushless, while the DC drive is the least attractive. The PM BLDC drive has the ability to perform better than the Permanent Magnet Syn drive when comparing the two types of PM brushless drives. The use of existing drives in flagship EVs is summarized in Table 3.2. The application including the DC drives seems to be either no longer in use or is only offered in versions that emphasize simplicity. The use of the SR machine is unusual. The market for electric vehicles is now split almost evenly between applications for induction drives and PM Syn drives. With the rising need for excellent efficiency and the rising worry for environmental preservation, it is predicted that induction power may progressively become obsolete while the PM BLDC drive gradually replaces it. Currently, the equivalent peak output power varies based on the weight and performance of the vehicle from 13 kW to 225 kW, with the average being between 47 and 80 kW (Chau 2014).

Table 3.2 Evaluation of existing EV drives

	DC	induction	SR	PM SYN	PM BLDC
Power density	2	3	3.5	4.5	5
Efficiency	2	3	3.5	4.5	5
Controllability	5	4	3	4	4
Reliability	3	5	5	4	4
Maturity	5	5	4	5	4
Cost level	4	5	4	3	3
Noise level	3	5	2	5	5
Maintenance	1	5	5	5	5
Total	25	35	30	35	35

Note: A point grading system (1 to 5 points) is used in which 1 is the worst and 5 is the best.

Table 3.3 Application of existing drives to flagship EVs

Drive types	**Car models**
DC	Fiat Panda Elettra, Citroën Berlingo Electrique, Reva G-Wiz DC
SR	Chloride Lucas
Induction	GM EV1, BMW Mini E, Tesla Roadster, Reva G-Wiz i
PM Syn	Nissan Leaf, Mitsubishi i-MiEV, Ford Focus Electric, Citroën C-Zero, Peugeot IOn, BYD e6
PM BLDC	Smart For two ED

3.1.3 Power Electronics

Power electronics are the techniques that made it possible for EVs to compete with ICEs. The closed-loop control system of the motor, power switching devices, and power converter topology make up this (Rajashekara 2013). The power systems, such as the thyristor, insulated-gate bipolar transistor (IGBT), static-induction transistor (SIT), static-induction thyristor (SITH), gate turn-off thyristor (GTO), power bipolar-junction transistor (BJT), power metal-oxide field-effect transistor (MOSFET), and MOS turn-off thyristor (MTO). Modern EVs nearly solely employ IGBTs. But certain low-voltage, low-power electric cars can also employ the mosfet that is certified for that purpose (EVs). To attain high voltage gain and great efficiency, dynamic power topology are frequently used, good controllability, and highly reliable (Chau and Wang 2005). Such power converters act as a bridge among the controller, electric motor, and energy-storage system (Schaltz and Soylu 2011). The topologies of the power converters are also based on the motors that will be operated. The obligatory requirements and the desirable requirements may be used to categorize the traction motor selection criteria for electric vehicles (EVs), which also includes the motors and their power converters. The motor drive must be able to meet the torque-speed needs of the EV driving profile without employing a gearbox or adjustable shifting, and it must have the capability of bidirectional power flow to recover regenerative braking energy. In general, Direct, and alternating Current, or SR motor drives may be able to provide the needed torque-speed requirements with an appropriate motor design. Cheap, high accuracy, powerful density, great operability, and maintenance-free operations are recommended qualities for fully electric drive systems (Chau and Wang 2005). Electronic and electro - mechanical controllers are the two distinct types. Whereas the electrical equipment offers soft start functionality, variable frequency, and vector-controlled drives, the electromechanical machines employ contactors/relays to stop, start, and reverse the direction of the motor. There should also be programming to react to system unit scans (Schaltz and Soylu 2011).

3.2 METHODOLOGY

A simulation employing accurate component models is necessary for EV performance prediction. The performance and energy consumption of an EV with a DC motor drive system were evaluated using a MATLAB simulation programme that includes models of the vehicle, motor, inverter, and lithium batteries. The software makes use of as many variables as are practical to achieve this objective. For the simulation, a number of mathematical models were used.

3.2.1 Block Diagram and Flow Chart

Fig. 3.3 depicts the elements of the EV propulsion system as a block diagram. The suggested lithium battery has a nominal 300V dc supply voltage. In order to power a DC motor, this uses an automated transmission to move the axles. The PWM inverter transforms the DC voltage into a variable-voltage variable-frequency (VVVF) DC voltage.

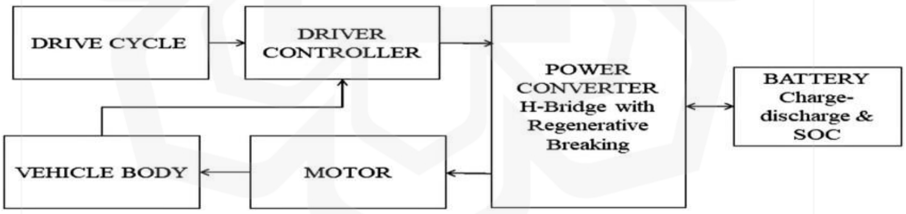


Figure 3.3 Block diagram of electric vehicle modelling

To charge the batteries during regeneration, the inverter converts ac power into dc while the induction machine acts like a producer. Regenerative braking doesn't require any extra parts to work. A PWM pulse generator controls the inverter's switching. The driving command and the feedback signals from the wheels, inverter, and batteries are sent into the controller unit to control the PWM circuit. The circuit then regulates the VSI's output frequency and voltage in accordance with the planned approach.

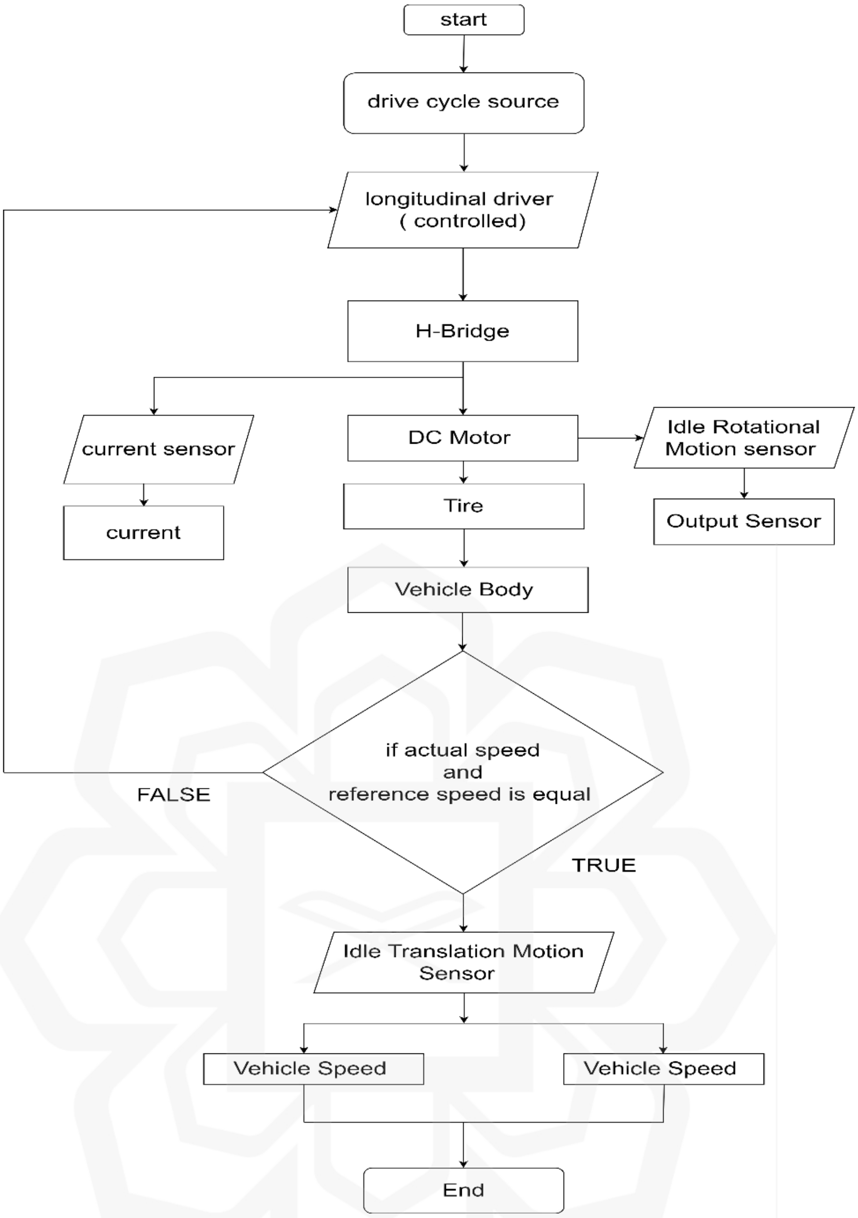


Figure 3.4 Flow chart of electric vehicle modelling.

The process for modelling electric cars is shown in Figure 3.4. The input of the driving cycle is the feedback from the braking and accelerator pedals. The longitudinally driver system controls its input from the drive cycle supplier. The driver controller has access to three inputs: standard speed, movement feedback, and slope, as well as three outputs: information, acceleration, and deceleration. The output from the driver controller is sent to the H-bridge using a Simulink to Real Data Convert and controlled PWM voltage. The required pulse width for activation is five volts. The H-Bridge is powered by internal power supply. The battery is used to switch the DC motor.

The battery is connected to the motor through a power converter to provide control action. The power converter modifies the voltage supplied to the motor. The DC motor is connected to the axle of the vehicle. The vehicle body's components include velocity, hub, wind, beta, NR, and NF. The usual rear force on the body is connected to the vehicle's rear wheels. The normal front force on the body is related to the front wheels of the vehicle. The wheel hubs are joined to the vehicle body. The driver controller must keep track of the vehicle's real speed so as to meet drive cycle data. By contrasting the speed limit and the current speed, it establishes the inaccuracy. The controller employed is a proportional integral controller.

3.3 VEHICLE MODEL

3.3.1 Tractive Effort

The battery within the automobile either supplies some or all the propulsion power and energy, depending on how an EV is actually constructed. Without losing its breadth, the subject of this section features an all-electric car (EV). The engine in an EV must deliver power for the car in all types of driving situations and road conditions, much like those in conventional vehicles. An EV must also be able to guide regenerative braking to collect and save the kinetic energy of moving vehicles in batteries for later use. The acceleration of a moving object is defined by all of the forces acting on it, in accordance with Newton's second law.

$$f_m \, M \, \alpha = F_t - \sum F_r \quad (1)$$

Where M is represents the vehicle's total mass, a is the car speeding up, f_m is the mass conversion factor that transforms spinning components' rotational inertias into corresponding translational mass, F_t is the vehicle's overall traction force, $\sum F_r$ is the overall force of resistance. Rolling resistance between tyres and the road surface, aerodynamic drag, and uphill grading resistance are typically the resistive forces. It is possible to estimate the overall resistance as (Young, Wang et al. 2013).

$$\sum F_r = Mg\, C_{rr}\ \cos\theta + \frac{1}{2}\ \rho\, A\, C_d\ (V - V_w)^2 +\ Mg\ \ \sin\theta \quad (2)$$

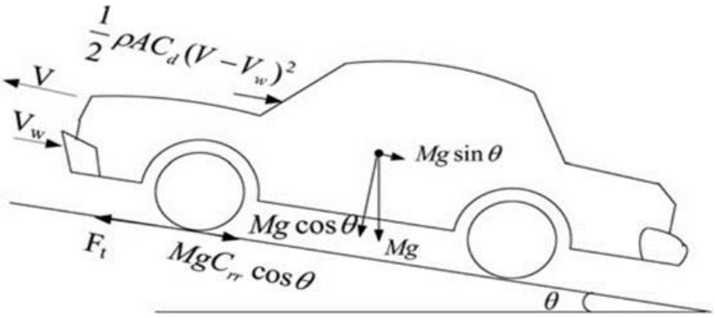


Figure 3.5 Forces applied on a vehicle (Young, Wang et al. 2013).

3.3.1.1 Aerodynamic Resistance

The air resistance to a vehicle's motion is known as aerodynamic drag. The definition of the aerodynamic drag force operating on the vehicle as,

$$F_D = \frac{1}{2}\ \rho\ A\ C_d\ (\ V - V_w)^2 \qquad (3)$$

Where ρ is the air density,

CD is the aerodynamic drag factor,

A is the car's cross-sectional size,

V is the vehicle speed in m/s, and $Vw$is the wind speed in m/s.

Drag rises or falls going to depend on the vehicle's compatibility travelling into a head or a tailwind and increases or reduces with the vehicle's cross-sectional dimension. Positive increases in drag result from a vehicle's trajectory speed being faster than the wind speed, which is the reverse of the vehicle's motion (headwind) (V + V_w). In this instance, a negative decrease in the drag of the load is caused by the combination of the vehicle speed and the velocity of the wind trajectory in the tailwind (the appropriate direction). ($V\ -\ V_W$). According to the form of the vehicle, the aerodynamic resistance coefficient is calculated experimentally (Goodarzi 2018),

Table 3.4 Vehicle Type and CD

Vehicle Type	**CD**
Cabriole	0.5 – 0.7
Car	0.3 – 0.4
Bus	0.6 – 0.7
Truck	0.8 – 1.5
Optional design	0.2 – 0.3

3.3.1.2 Rolling Resistance

The total frictional force generated by the drivetrain's friction and the tire's deflection on rolling force refers to the condition of the pavement. The equation describes rolling resistance,

$$F_R = M\ g\ C_{rr}\ \cos\theta \quad (4)$$

Where M is the car's mass [kg], g is the gravitational acceleration force, nominally 9.81 m/s2, and the rolling resistance coefficient is abbreviated CR, rolling resistance is obviously impacted by the vehicle's load. The factor of friction force is mostly constant at slow speeds. Even while it rises at high rates of speed, the consequences are less noticeable because drag is mostly responsible for vehicle lost. Increase pressure tires are used by EVs to reduce rolling resistance. The average result of an EV tyre is 0.01 or less. The rolling resistance coefficient (Cr) fluctuates based on the condition of the road.

Table 3.5 Road Surface and CR

Road Surface	**CR**
Concrete or Asphalt	0.013
Small Gravel Ground	0.02
Macadamized Road	0.025
Soil Road	0.1-0.35

3.3.1.3 Gradient Resistance

Depending on whether the vehicle is travelling up or down a hill, the load force might change. It is possible to measure the gradient strength or climbing resistance as.

$$F_c = m\ g\ sin\theta$$

Where $\boldsymbol{F_c}$ the gradient's resistance, $\boldsymbol{\theta}$ the angle of inclination and $\boldsymbol{g}$ the speed of gravitational acceleration. The force is positive while the automobile is in motion during motor operation. In the event of a negative force, the vehicle's velocity is reduced, and this mode may also cause energy storage restoration to be used to slow the electric car rather than the brake disc. The gradeability of a vehicle refers to the curve it can travel up at a given speed. It is also known as the tangent of the inclination angle or the ratio of climb to descent. It is sometimes expressed as a proportion, with tan 45° equalling 100%. Table 3.6 shows several inclination angles and values (Goodarzi 2018).

Table 3.6 Incline angles and grade.

Incline (°deg)	Grade (%)
0	0
6	10.5
45	100

Following that, the overall propulsive force may be represented as

$$F_t = f_m\, M\, \alpha + Mg\, C_{rr}\, \cos\theta + \frac{1}{2}\, \rho\, A\, C_d\, (V - V_w)^2 + Mg\, \sin\theta \qquad (5)$$

The power to drive the vehicle at speed V is then.

$$P = F_t\, V = f_m\, M\, \alpha\, V + Mg\, C_{rr}\, V\, \cos\theta + \frac{1}{2}\, \rho\, A\, C_d\, V\, (V - V_w)^2 + Mg\, V\, \sin\theta$$

(6)

For a car travelling on a level road (θ = 0), early in the acceleration process, the primary functions of the propulsion power are vehicle acceleration and rolling resistance reduction. Once the desired velocity has indeed been reached, the roll resistance and aero drag force must be overcome, the power is utilised to maintain the speed. The battery power capacity of an electric vehicle must be adequate to fulfil acceleration needs. When regenerative braking is used, an EV's electric propulsion motor at the beginning of acceleration for a car travelling on a level surface (y 14 0), the functions as a generator to convert mechanical work from moving the automobile into electrical energy to recharge the battery. Here's how the brakes power may well be explained. (Young, Wang et al. 2013).

$$P_b = F_b\, V = f_m\, M\mu\, V + Mg\, C_{rr}\, V\, \cos\theta + \frac{1}{2}\, \rho\, A\, C_d\, V\, (V - V_w)^2 + Mg\, V\, \sin\theta \qquad (7)$$

3.3.2 Battery Model

An accurate battery behaviour model is crucial for simulation studies, analysis, and the creation of control techniques for EVs. In the model-based battery management system, they are especially important for precise battery state estimates. The most current study includes seven contemporary battery models and equations, includes the Rint version, Thevenin idea and combination, Rint , Unnewehr Universal , as well as Double Polarization (DP) model are a few examples. Considering the outcomes of the numerous scientific tests, it must have been found as a Dual Polarization Approach works more effectively dynamically as well as because voltage reduction is modelled in a more elegant manner. In essence, a modified Thevenin model is the dual polarization (DP) version. That was created via considering the polarisation properties of the lithium-ion battery. Internal resistances, equivalent capacitance, and UOC open circuit voltage make up the three primary components of the DP model. The ohmic resistance (Ro) makes up the inner impedance, Electro-chemical polar resistance (Rpa) and concentration polarization resistance (Rpc). The concentration polarization and electrochemical capacitances, Cpa and Cpc, which stand in for the charging/discharging transits transient response, make up the equivalent capacitance. Fig. 3.6 serves as an example of the electrical operation of the circuit.

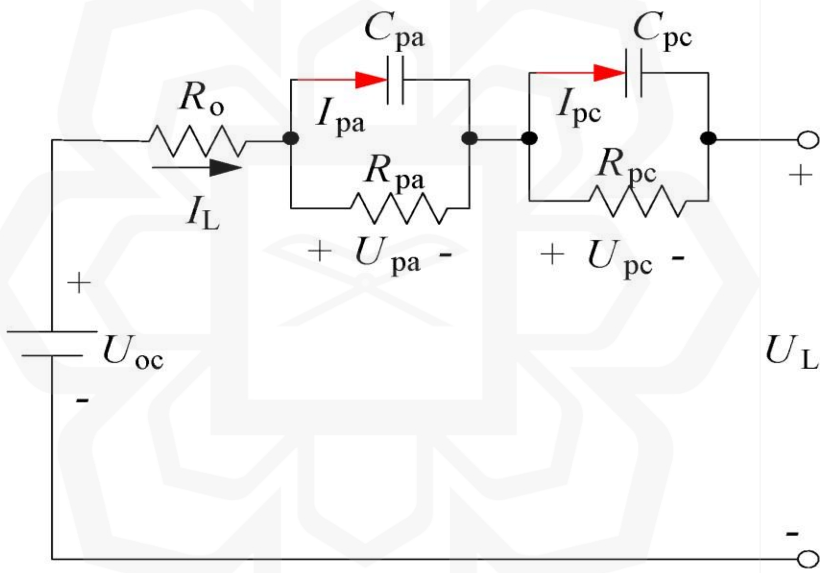


Figure 3.6 DP model battery equivalent circuit (S and P.S 2019).

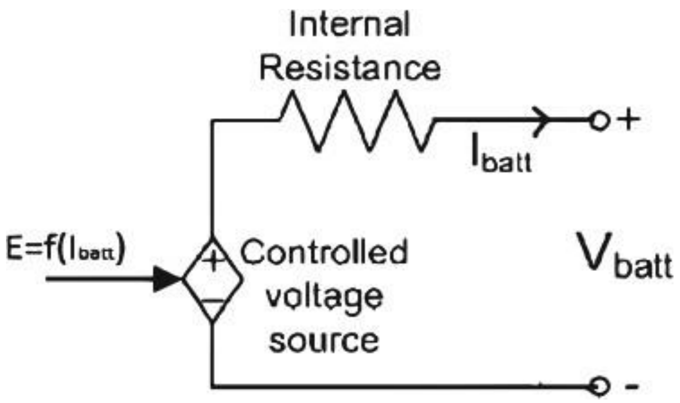


Figure 3.7 Nonlinear battery model (S and P.S 2019).

$$\mathring{U}_{pa} = \frac{-U_{pa}}{R_{pa}\ C_{pa}} + \frac{\mathrm{iL}}{\mathrm{C_{pa}}} \tag{8}$$

$$\mathring{U}_{pa} = \frac{-U_{pc}}{R_{pc}\ C_{pc}} + \frac{iL}{C_{pc}} \tag{9}$$

$$U_L = U_{oc} - U_{pa} - U_{pc} - iLR_o \tag{10}$$

The sole variable needed for this straightforward model is the battery State-Of-Charge (SOC), which simplifies the algebraic solution. The design that can exactly identify four variants of battery chemistry is easy to use since the values may well be simply calculated from the discharging bend that the producer has provided using the advised technique.

$$E = (\ \mathrm{I_{batt}}\ ) = E0 - K\ \frac{Q}{Q-I_t} - i\ t + A.\ exp(-B.\int idt) \tag{11}$$

Fig. 3.8 depicts the battery model, and formula for the controlled source that describes it may be expressed like in (S and P.S 2019).

$$\mathrm{V_{batt}} = E - i.\ R \tag{12}$$

3.3.3 Motor Model

The most often utilised devices as variable speed drives are still DC motors. The techniques used to simulate DC machinery are far easier and less complicated than those used to represent AC machines. Controlling DC motors is made easier thanks in part to advancements in the design of controlled rectifiers and DC-DC converters (Yildiz 2012). DC motors are regarded as the greatest kind of motors in terms of regulating speed with high precision and precise increments. A series DC motor made for traction purposes was controlled using a real-world case study. Using this kind of motor has the benefit of allowing you to change the direction of rotation by flipping the polarity of the input voltage. The high torque of this motor is likewise related to the square of the load current (Bitar, Al Jabi et al. 2014). The comparable circuits for the DC machine are depicted in Figure 3.8. The typical representation of a brushed motor is two brushes making contact with a supply voltage of return emf Ea. Inductance of the armature winding La and the comparable series resistance of the armature (Ra) are two internal motor parts that are obviously a part of the motor, yet they are usually identified in circuit diagrams as separate external components (Goodarzi 2018).

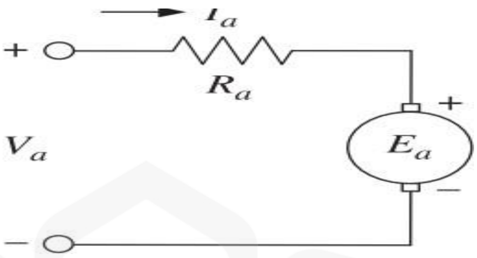


Figure 3.8 Equivalent circuit of dc motor (Goodarzi 2018).

The terminal voltage falls to the steady state equation.

$$Va \ = E_a \ + R_a \, I_a \qquad (13)$$

The terminal voltage Va and the produced back emf Ea. have a substantial connection. Formula relating to torque Tem and back emf explain the electromechanical behaviour of the DC machine:

$$T_{em} = \frac{p}{2} \, \lambda_f \, I_a \qquad (14)$$

And

$$E_a = \frac{p}{2} \, \lambda_f \, \omega_r \qquad (15)$$

Where ω_r is the rotor angular speed, λ_f is the field-excitation magnetic flux linkage, and p is the number of magnetic poles. a constant k is used as follows:

$$T_{em} = kI_a \qquad (16)$$

$$E_a \ = k\omega_r \tag{17}$$

Where

$$k = \frac{p}{2}\, \lambda_f \tag{18}$$

The voltage and torque formulas can be utilized to determine a connection among both torque and speed.

$$Va \ = k\omega_r + \frac{R_a}{k}\, T_{em} \tag{19}$$

You can calculate the torque using the voltage source and rotation velocity:

$$T_{em} = \frac{k}{R_a}\, V_a - \frac{k^2}{R_a}\, \boldsymbol{\omega_r} \tag{20}$$

The machine's electromagnetic generator is powered by (Goodarzi 2018)

$$P_{em} \ = T_{em}\, \omega_r \frac{k\, Va}{R_a}\ \omega_r - \ \frac{k^2}{R_a}\ \omega_r^2 \tag{21}$$

3.3.4 Transmission Model

The gearbox system's job would be to transfer motor speed to the axles that are really doing the drive. Efficiency of the transmission system, which is characterized in both traction and regeneration modes, has an impact on the energy consumption of EVs:

$$\eta_{g_{traction_{mode}}} = \ \frac{T_{wheels} \cdot \omega_{wheels}}{T_{motor(s)} \ \cdot \ \omega_{motor(s)}} \tag{22}$$

$$\eta_{g_{regenertive_{mode}}} = \ \frac{T_{motor(s)} \cdot \omega_{motor(s)}}{T_{wheel\,s} \ \cdot \ \omega_{wheel\,s}} \tag{23}$$

Where ω wheels and ω motor(s) are the wheels and the motor speed respectively in (rad/s), T wheels is the torque at the driving wheels in (Nm) and T motor(s) is the motor torque in (Nm).

The transmission model is derived based on the following equation:

$$\mathrm{F_T} = \frac{T_{motor(s)}\ .\ G\ .\eta_G}{r_d} \qquad (24)$$

While FT stands for tractive power in Newton's (N), G for single-speed gear ratio, rd for dynamic tyres diameter in meters, and G for estimated 97% transmission efficiency. (Miri, Fotouhi et al. 2021)

3.3.5 Inverter Model

Because of its decreased harmonic output and zero switching loss, the power transistorised PWM resonant dc link inverter was chosen. The specifications utilised in this thesis' simulation studies. The dc voltage coming in v_d is related to the output phase fundamental rms voltage V_t of the VSI as follows:

$$V_d = k_u\, v_1 \qquad (25)$$

Where k_u is determined by the inverter output voltage wave. When the conducting angle

Is $180°, K_u = \frac{1}{\sqrt{2}}\,\pi\ when\ 120°$ $\qquad K_u = \sqrt{\frac{2}{3}}\ \pi\ ;$ when PWM

Ku is determined by

The carrier ratio and PWM technique. Typically, symmetric triangular modulation is used in VSI PWM. We can get the whole bridge inverter's Fourier analysis results:

$$V_1 = a_n \sin k\omega t \qquad (26)$$

$$\frac{2\,V_d}{k\pi} \quad \left[1 + 2\,\sum_{i=1}^{j} (-1)^i \cos k\alpha i\right] \text{Sin k}\omega t \qquad (27)$$

Where k harmonic order, k = 1,3,5,7; *i* number of pulses per half-cycle.

j chopping angle number per half-cycle (switching angle); a voltage pulse angle in front or rear side, which can be decided according to carrier ratio and modulation ratio by the system control and a, must satisfy

$$0< a_1 \ < a_2 \ < \cdots < a_1 < \frac{\pi}{2} \ .$$

Only the essential component is taken into consideration for steady state and PWM. The PWM control mathematical model is challenging. Consider a 180° conducting inverter as an example to simplify.

$$V_d = \frac{\pi}{\sqrt{2}}\, V_1 \qquad (28)$$

$$I_d = \frac{p_i}{\eta_i\, V_d} \text{………………..(29)}$$

Where V, output phase voltage of VSI
V_d Input dc voltage of VSI
I_d Input dc current of VSI
η_i Inverter efficiency (Fan 1994)

3.4 SUMMARY

Software was used to develop the numerical technique for analysing a battery-powered DC drive system of an EV in either the driving or regeneration mode of operation. To assess the energy and power needs of automobiles throughout typical driving cycles for various route profiles, utilise the computer programme MATLAB software.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 BENCHMARK

The correctness and validity of a computer simulation's component models determine how reliable the findings will be. Most of the major vehicle and drive component models' performance can be predicted quite easily thanks to design and operating expertise. On the other hand, accurate modelling is a fascinating problem due to the complicated behaviour of batteries, particularly in an EV application with its vast diversity of uses. The FTP-75 cycle, as seen in figure 4.1, was used throughout the study presented here to base comparisons of the EV performance anticipated by the simulation programme with test or simulation findings from other references. Gear ratios are set in stone.

Table 4.1 Vehicle and driving cycle Characteristics Validation

parameters	**Reference (Mohd, Hassan et al. 2015)**
vehicle mass (kg)	1230
aerodynamic drag coefficient	0.324
rolling resistance coefficient	0.014
frontal surface area of the vehicle (m2)	2.26
air density (kg/m3)	1.204
motor type	DC

Vehicle characteristics are outlined in Table 4.1, which also compares them to simulation results from Reference (Mohd, Hassan et al. 2015). It is clear that, for the identical vehicle parameters, the calculation results from the MATLAB Simulink programme are quite close to those in Reference (Mohd, Hassan et al. 2015). According to figure 4.2.

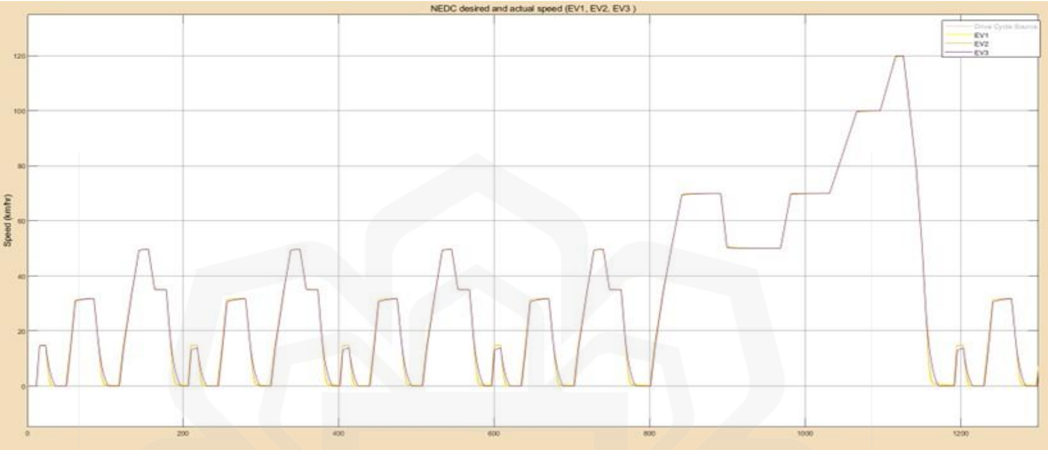


Figure 4.1 FTB-75 (1300 second) simulation driving cycle

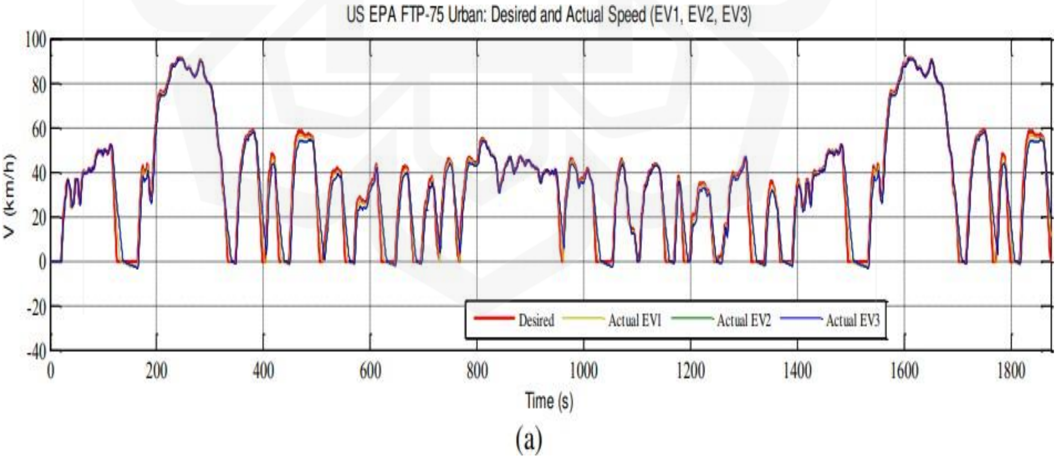


Figure 4.2 Vehicle Speed vs time reference (Mohd, Hassan et al. 2015).

4.2 SIMULATION MODEL

For automakers, developing electric vehicles requires a significant investment. These businesses use a number of sophisticated software techniques to simulate that a car design would function in various test scenarios. Engineers can experiment with different settings to get the desired outcomes by analysing these simulations to gain more insight into the design process. By tracking the results of simulations, manufacturers can determine expenses and streamline the design process. In this study, the electric vehicle under consideration is modelled and simulated in MATLAB/Simulink. The Battery Electric Vehicle Simulation Component was chosen to mimic the BEV. The simulations model has four important subsystems: the car structure subsystem, the powertrain circuits and controller’s subsystem, the drivers’ inputs sub - system, and the car battery subsystem.

4.2.1 Driver Input Subsystem

Figure 4.3 depicts the application of input supply with driver controller. A multiport switch is utilised in this area of the Simulink code to calculate the desired signal speed, expressed in km/h. After choosing the reference speed source, it must be connected to the longitudinally Drive Generators (LDG). The LDG should estimate the acceleration and braking out from baseline speeds input. The Motor Controller Subsystem receives a variable value from the LDG output that ranges from zero to one (MCS).

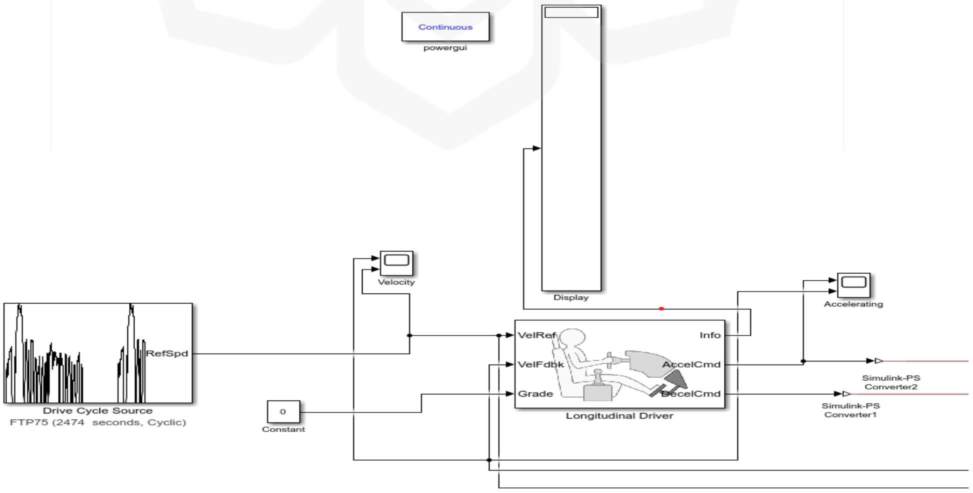


Figure 4.3 Driver Input Subsystem

4.2.2 Motor Circuit and Controller Subsystem

The hardest part of the code is the MCS portion. Through two regulated voltage sources, this subsystem transforms the LDG's braking and acceleration source signals into an electrical reference. The sign provides the PWM regulator with a number of inputs, it sends an H-Bridge pulse width modulation signal as its output and so controls the operation of the motor. The Simulink code sent to the PWM controller is displayed in Figure 4.4 as Control Subsystem Part I. The left side reference lines of Figure 4.5 are linked to the output signals to the right of the pulse width modulation controller.

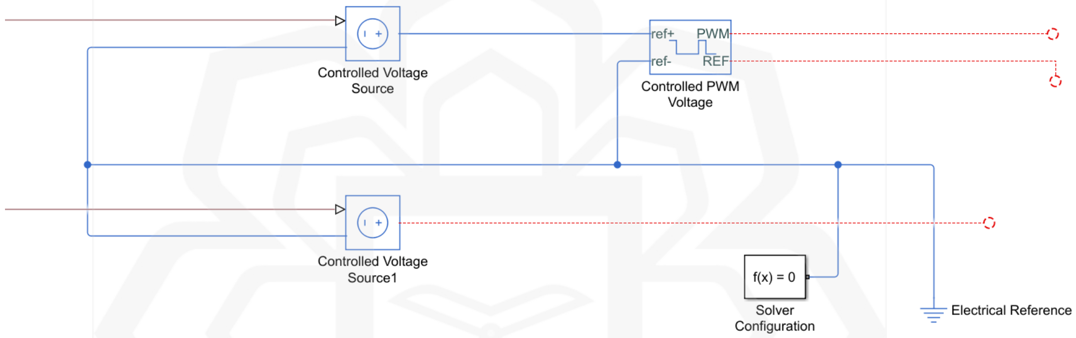


Figure 4.4 Control Subsystem Part I

Management Sub - system Part II displays the sign transmission out from Pulse width of Figure 4.4 into the H-PWM Bridge's standard inputs (Figure 4.5). Both voltage and capacity of the external DC battery that powers the H-Bridge are chosen using an original automotive simulation. This H-Bridge then controls the speed and polarities of the Direct Current motor to match the input references as closely as is practical. The positive terminal of the battery is also linked in series with a current sensor. By monitoring the battery's current amount, applying a yield in series, integrating with respect to time, then subtracting that value by 1, it is possible to view the total battery capacities during driving cycle.

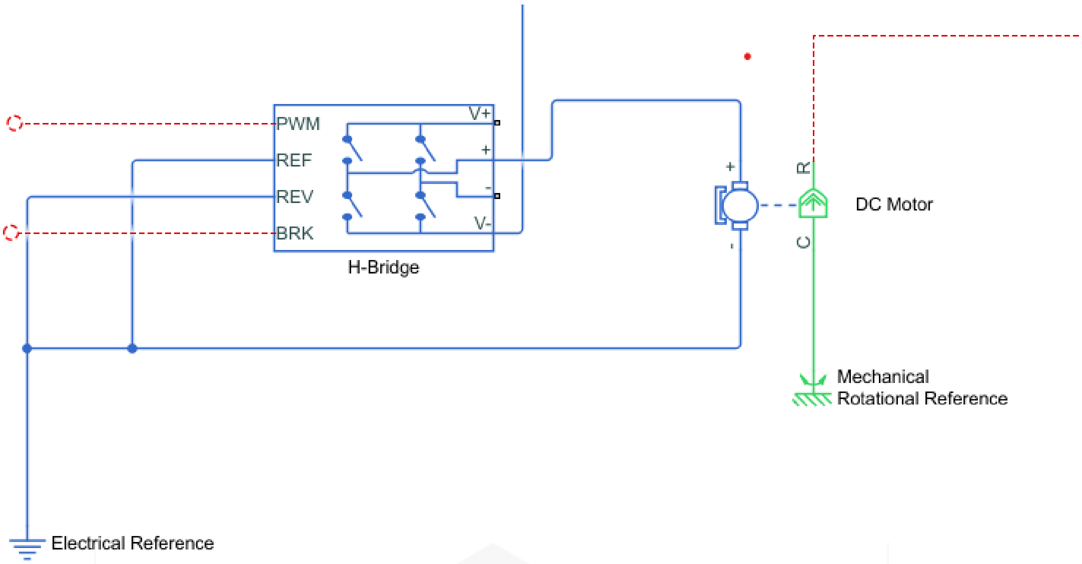


Figure 4.5 Control Subsystem Part II.

4.2.3 Vehicle Body Subsystem

The subsystem for the vehicle body is shown in Figure 4.6. By replicating a gearbox, tyre arrangement, and the vehicle body, this component creates a physical simulation of a car. The gearbox combines the powertrain with such a user-defined specific ratio and produces the rotation speed like a result with this proportion. The car can calculate the rolling radius and rolling resistance of the tyres using their appropriate Magic Formula Coefficients. Depending on the drive train design, the chassis replicates angular velocity by translating the typical force produced by the wheels in a two-axle configuration. Rear-wheel movement is represented by the wheels in the diagram.

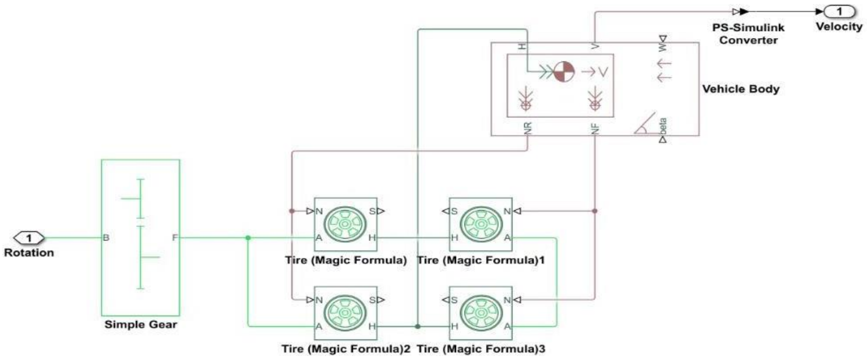


Figure 4.6 Vehicle Body Subsystem

4.2.4 Battery Pack Subsystem

The engine will be powered by the battery pack. The Charge State computation would let us know how long and how extensively we may use an energy storage before we need to recharge. In order to directly examine the SOC %, I utilised a lithium-ion battery. With the aid of SOC, we can evaluate battery charging and draining. The connections between each block to form a subsystem are shown in the diagram below.

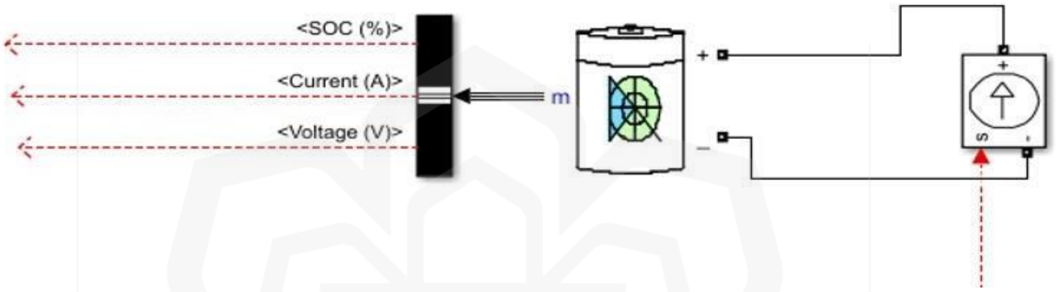


Figure 4.7 Battery Pack subsystem

4.2.5 Overall Model

Adding a monitor block and a powergui component to the simulation will let you observe the results and actions of the electric vehicle model. My reference signal was the driving cycle. Once the reference voltage and real frequency are displayed on a single chart, the operation of the feedback loop will become obvious. We can also determine the normal speed of the electric vehicle. We may see how the battery charges and discharges during a command for acceleration or deceleration with the use of the SOC graph. The figure below shows the whole electrical simulation I was using to analyse the car's SOC% and mean velocity Figure 4.8.

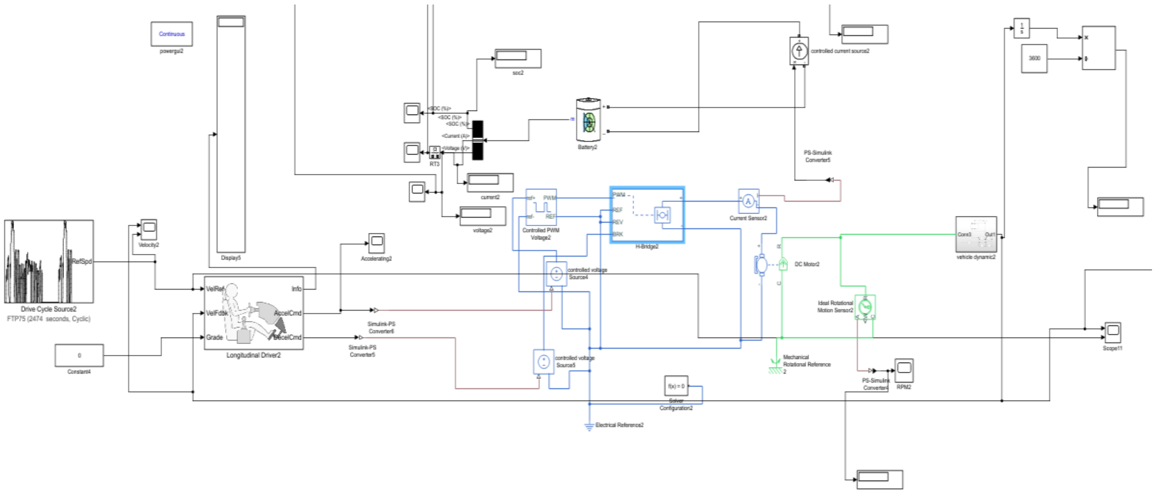


Figure 4.8 Overall Simulink Model of electric vehicle

4.3 PARAMETER IMPLEMENTATION

The material in this part focuses on the variables we picked and the features of our simulation's adaptability. The table 4.2, "Vehicle Simulation Parameters" collects the numerous traits of each automobile and serves as a guide for the block parameters. To put these unique characteristics into practise. A first Simulation component that requires input data is the DC power supply. Voltage of the car's battery and capacity are its two most crucial features. The power supply from the H-Bridge send to the motor is also impacted by the voltage supply.

Table 4.2 Vehicle Simulation Parameters

System Parameter	EV1 Ford Ka 2008	EV2 Ford Focus 2007	EV3 BMW 7 Series 2002
System Voltage	300	300	300
Rated capacity, Ah	100	100	100
No-load speed, rpm	4000	4000	4000
Rated speed, rpm	1000	1000	1000
Rated load, kw	260	260	260
Mass, M (kg)	940	1230	2150

wheel rad, rd (m)	0.18	0.20	0.23
Front area, A_f (m^2)	2.11	2.26	2.38
Drag coefficient, C_d	0.337	0.324	0.290
gravitational acceleration	9.81 ms^{-2}	9.81 ms^{-2}	9.81 ms^{-2}
Air density	1.204 kgm^{-3}	1.204 kgm^{-3}	1.204 kgm^{-3}
Rolling resistance coefficient	0.014	0.014	0.014
road slope angle	0	0	0
wind speed	0	0	0

The motor function subsystem's second movable unit, there are specifications for the field kind, no-loading rpm, operating speed, power flow, and DC supply voltage of the DC motor. Except for the no-load speed, all of these inputs are readily available in the vehicle's manufacturer's specs. The individual motor must be considered while estimating the maximum output speed. For DC motors, values generally range between 5,000 and 10,000 rpm. The positive and negative terminals of an H-Bridge are responsible for controlling the DC motor. The voltage source, load resistor, and electric field inductor are the components of the motor's equivalent circuit. For each simulation, the inputs for rotor inertia and damping may be changed.

Four wheels are the final set of special blocks that which convert the energy produced by the gear's driveshaft into normal and rotational motion. Magic Formula Coefficients, we build the fundamental parameterization totally using empirical methods that rely on such an equation to characterize the combination slipping and tyre force.

Separate rolling circles are also provided by the wheels, rolling resistances as well as other dynamic properties. In both simulations, the coefficients were derived internally using the Magic Tire Coefficient Formula.

The car's actual body is the last component is the building element that allows for the most user-defined settings to imitate actual vehicle movements. Among these variables are car weight, frontage area, drag coefficient, density of the air, and axel distances from the gravitational centre. These factors are used in this simulation.

4.4 RESULTS

Applying the intricate mathematical models of the system previously discussed in the MATLAB/Simulink® environment, the entire car powertrain has been configured, assembled, and given the proper connections as illustrated in figure 4.8. For the simulation, our model is ready. In this study, we model three sets of variables from various markets for electric vehicles, including (Ford Ka 2008 EV1, Ford Focus 2007 EV2, BMW 7 Series 2002 EV3). Within three driving cycle (NEDC, HWFET, FTP-75), it is critical that the simulation be able to drive a specified route with precision and repeatability to compare between these cars for analysing vehicle performance and energy consumption in various scenarios. Therefore, planned, standardised driving cycles must be used while running the simulation models. A velocity-time table is used to define a driving cycle, which is a standardised driving pattern. A track that the vehicles will travel over is specified by a driving cycle. The first drive cycle, which adheres to the NEDC condition test standard, is frequently used to evaluate the whole driving range of pure electric cars. Using this as a foundation, this part will demonstrate how the electric cars outperform motor direct drive electric vehicles in terms of postponing battery deterioration and lowering battery energy usage under NEDC conditions. The urban operating cycle and the suburban cycle make up the two components of the NEDC condition. The urban cycle is made up of four small-cycle units, each lasting 195 seconds, and includes multiple stages of idle speed, starting up, accelerating, and deceleration parking. According to Figures 4.9, the average cycle duration is 400 s, and the top speed is 120 km/h. However, the US EPA established the HWFET cycles, second drive cycle, which is a chassis dynamometer driving schedule for determining the fuel efficiency of light duty cars (Figure 4.10). It replicates a 16.45 km long highway trip in a time of 765 seconds, a real speed of 80 km/h. Federal Test Procedure (FTP-75) driving cycle, which is depicted in Figure 4.11, was employed for all simulations. To simulate city driving, one might utilise the FTP75 drive cycle. The first 505 seconds of the Urban Dynamometer Driving Schedule (UDDS) are what follows. With a dead interval in between the transient and hot start phases, it has three phases: the cold starting, transitory, and warm initiate. The hot start phase of the process is the portion that is repeated. After the catalytic converter has warmed up, it is made to monitor emissions (Tóth-Nagy 2000).

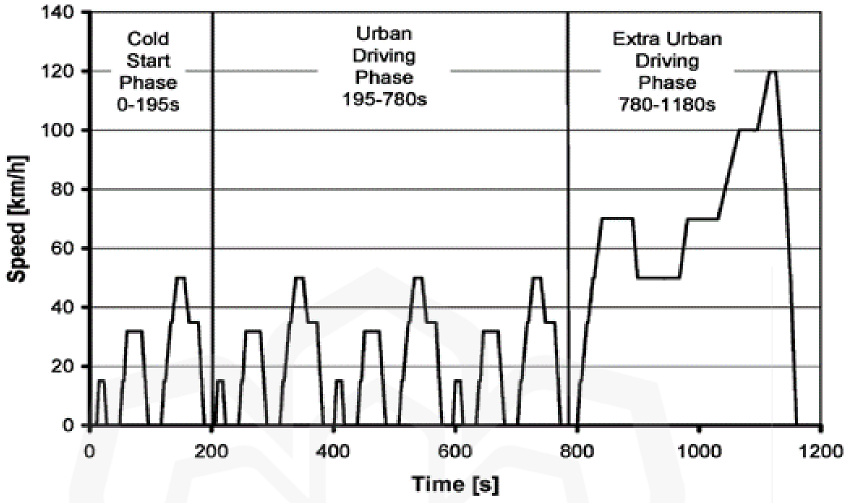


Figure 4.9 Vehicle speed versus time in the NEDC driving cycle (Konstantas and Stamatelos 2004).

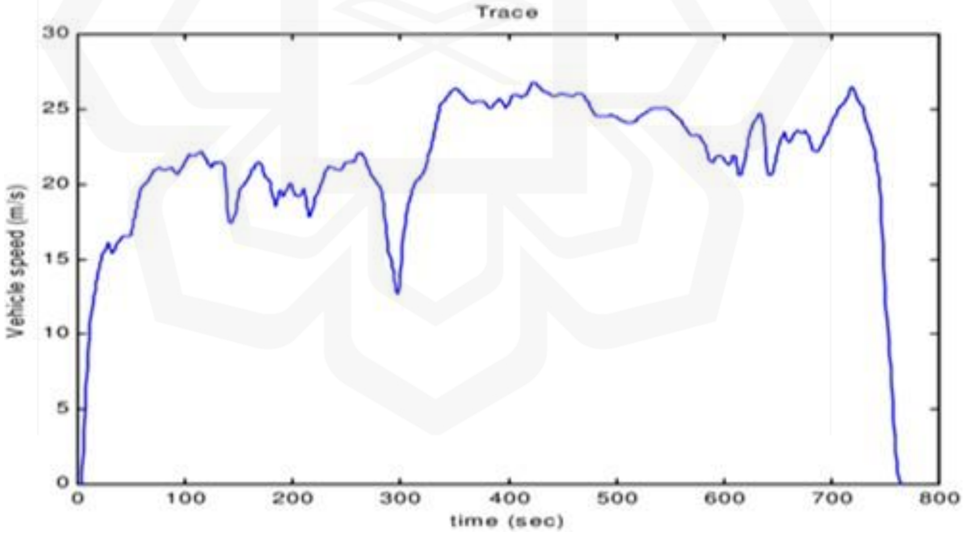


Figure 4.10 Speed vs. time on the HWFET cycle. (Jaafar and Rahman 2020).

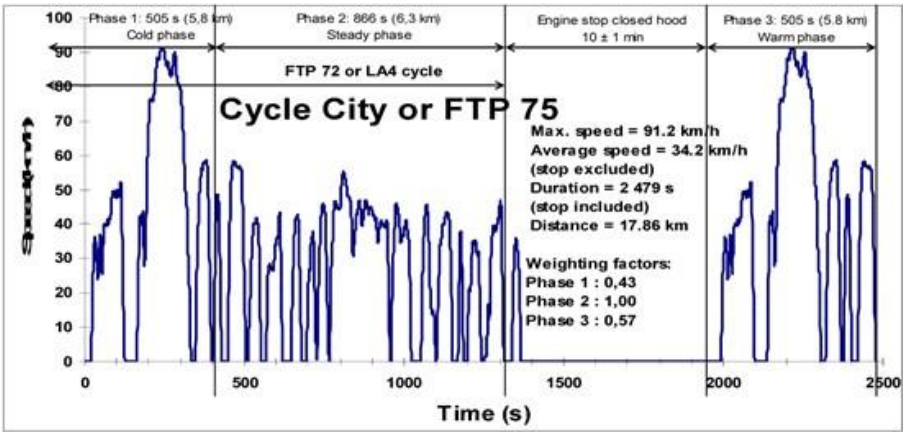
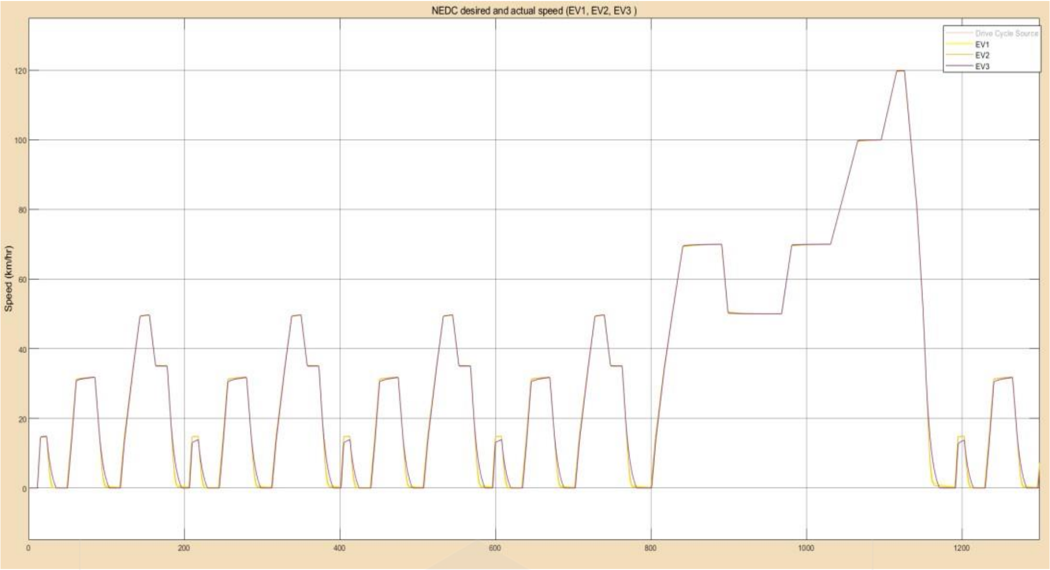
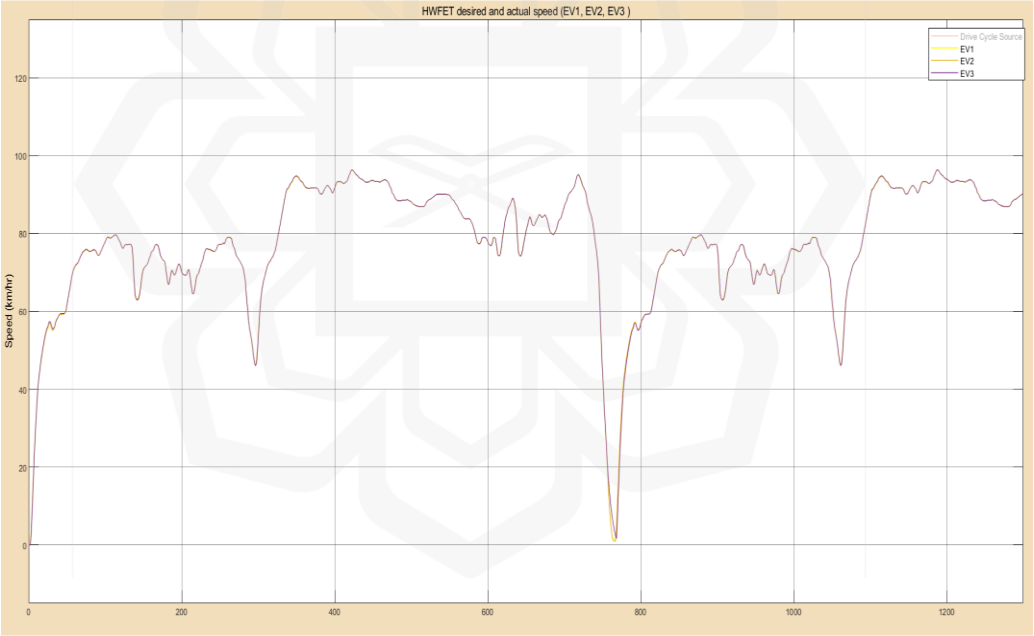


Figure 4.11Vehicle speed versus time during the FTP75 driving cycle (Zervas 2011).

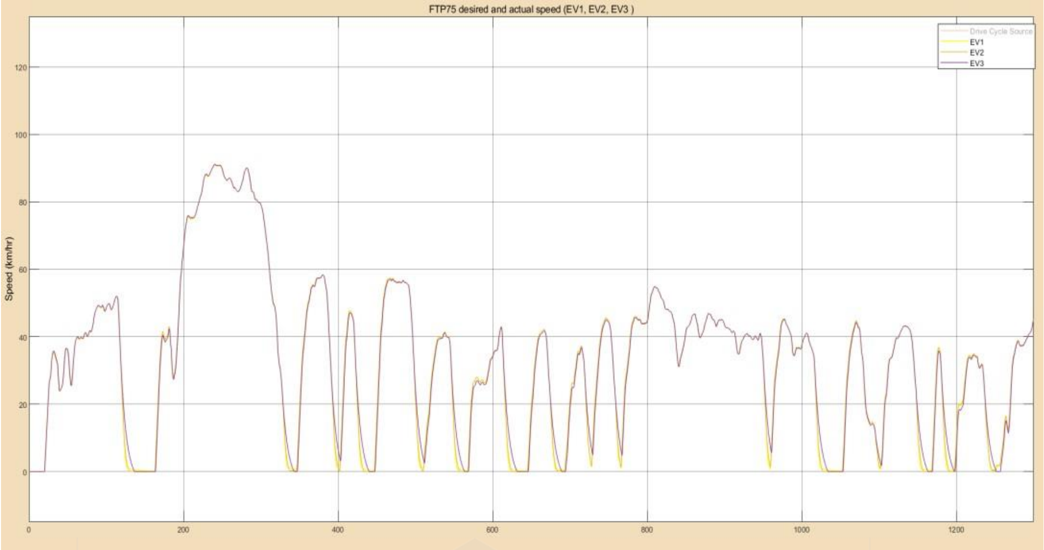
We perform a 1300-second drive cycle using our virtual simulation model using NEDC, HWFET, and FTP-75. For the car to continue moving once at driving cycle-specified speed, the PID controller, working in tandem with the driver, activates the accelerator and brake pedal locations to the motor. We are now going to provide some significant findings from our research. The three vehicles in Figure 4.12A, B, and C have undergone NEDC, HWFET, and FTP-75 driving cycle testing. The velocity curves perfectly match, as can be seen. When the vehicle speed and the driving cycle profile were perfectly in sync, we fine-tuned the PID controller in the vehicle controller component. The results often showed a minor mistake in every cycle, making it clear that the controller performed an excellent job of removing error. A distinct distribution of the inaccuracy may be seen in areas where the speed changes quickly (heavy fluctuations). The error grows with segment size, from EV1 to EV3, considering the variation in inaccuracy between sections. It occurs because three variables mass, wheel diameter, and frontal area increase as the section grows larger.


NEDC desired and actual speed (EV1, EV2, EV3)
Drive Cycle Source
EV1
EV2
EV3
Speed (km/hr)
120
100
80
60
40
20
0
0
200
400
600
800
1000
1200

(A)


HWFET desired and actual speed (EV1, EV2, EV3)
Drive Cycle Source
EV1
EV2
EV3
Speed (km/hr)
120
100
80
60
40
20
0
0
200
400
600
800
1000
1200

(B)

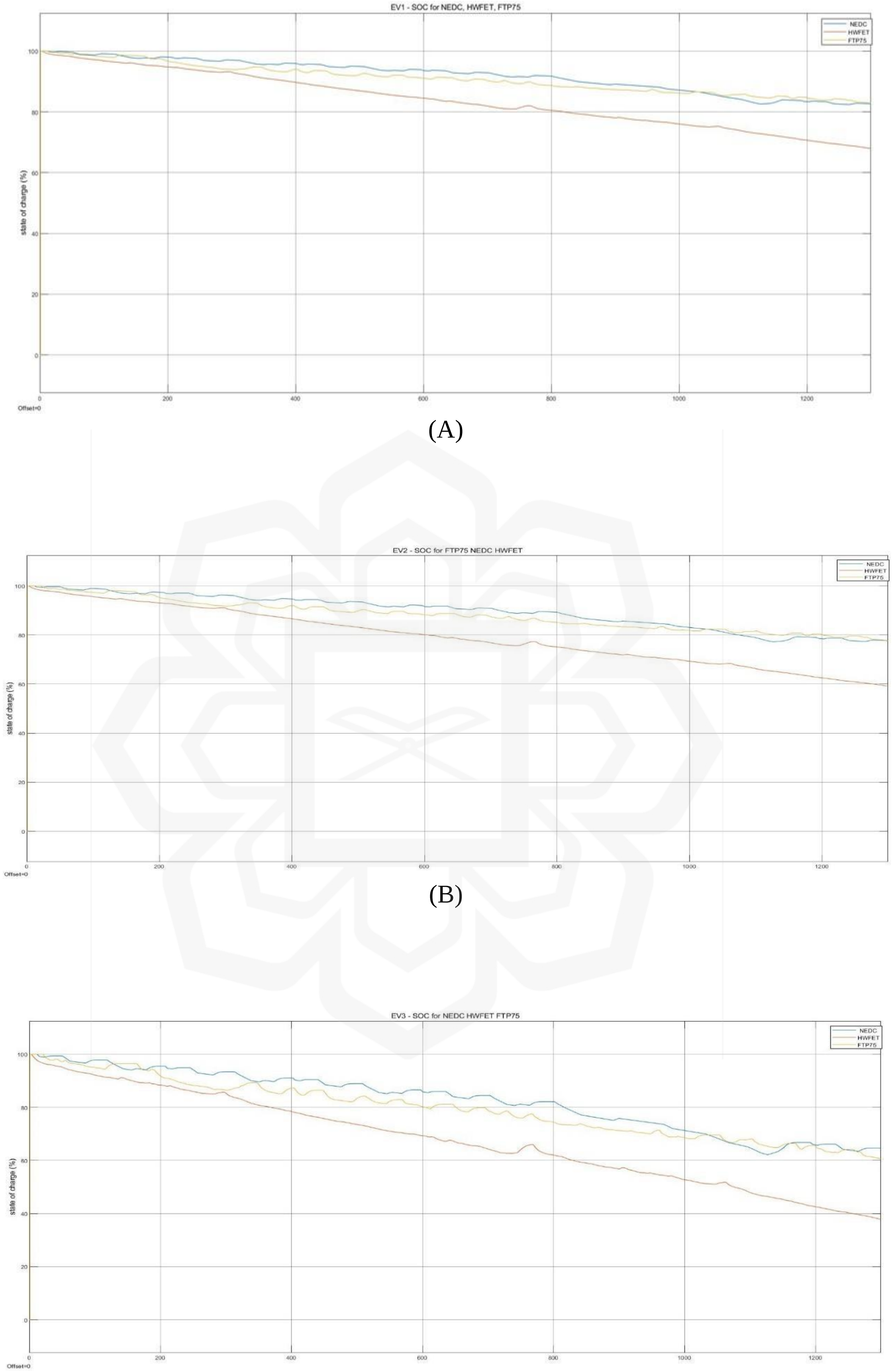


(C)

Figure 4.12 Simulation results of driving cycle desired with actual speed (EV1, EV2, and EV3) with NEDC (A), HWFET (B), and FTP75 (C)

4.4.1 Battery Simulation Analysis

The battery SOC is defined as the percentage of total capacity that is still available. The battery SOC across the run cycles is shown in Figure-4.14. All EV1, EV2, and EV3 segments exhibit the same pattern, as seen in the images. The FTP-75 urban cycle generally illustrates how discharge varies substantially as a result of the many stopping and beginning points. The discharge profile of the HWFET highway cycle is significantly more even. The most variable in discharge is the NEDC cycle, which combines an additional urban component (EUDC) with an urban part that is repeated four times (ECE). When comparing driving cycles, the HWFET cycle, which has the lowest fuel economy, has the largest percentage of charge drained. FTP-75 has the second-highest depleted charge, whereas NEDC has the lowest depleted charge and the best fuel efficiency. The EV1, EV2, and EV3 are the most economical vehicles across automotive categories, respectively. It is anticipated that increasing mass, wheel radius, and frontal area parameters will result in decreased fuel economy.



(A)

(B)

(C)

Figure 4.13 Simulation results of State of Charge (SOC) during three driving cycle EV1 (A), EV2 (B), and EV3(C).

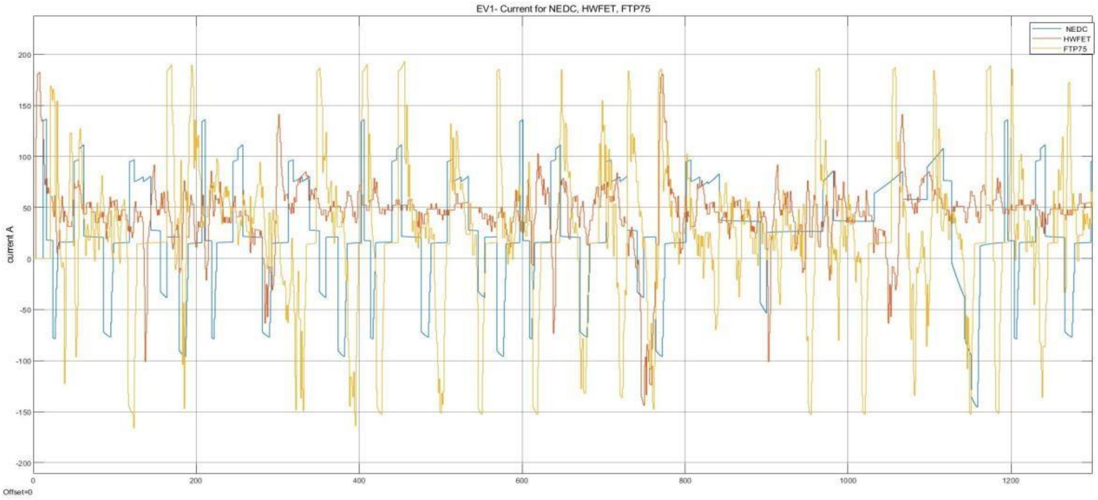


Figure 4.14 EV1 - Current for (NEDC), (HWFET), (FTP75)

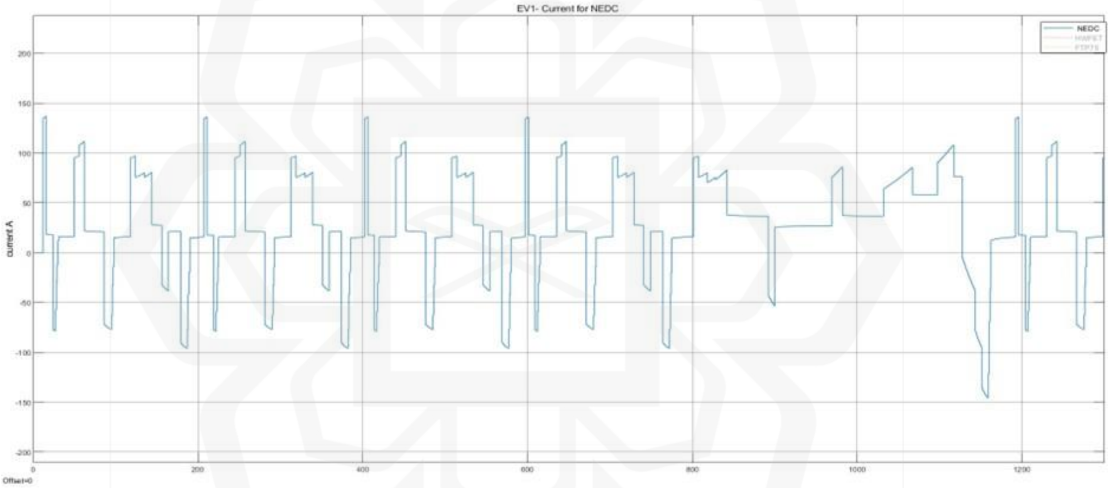


Figure 4.15 EV1 - Current for (NEDC)

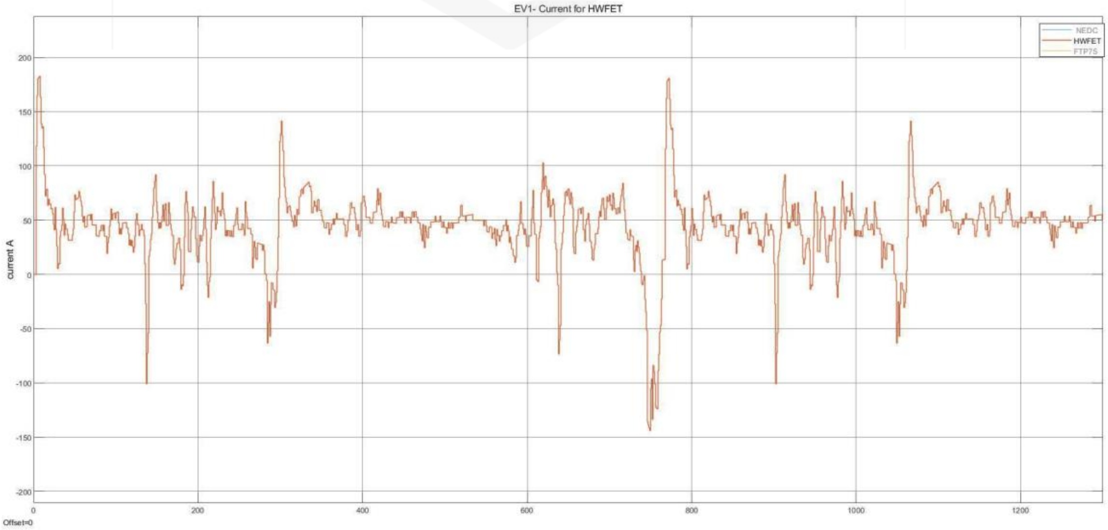


Figure 4.16 EV1 - Current for (HWFET)

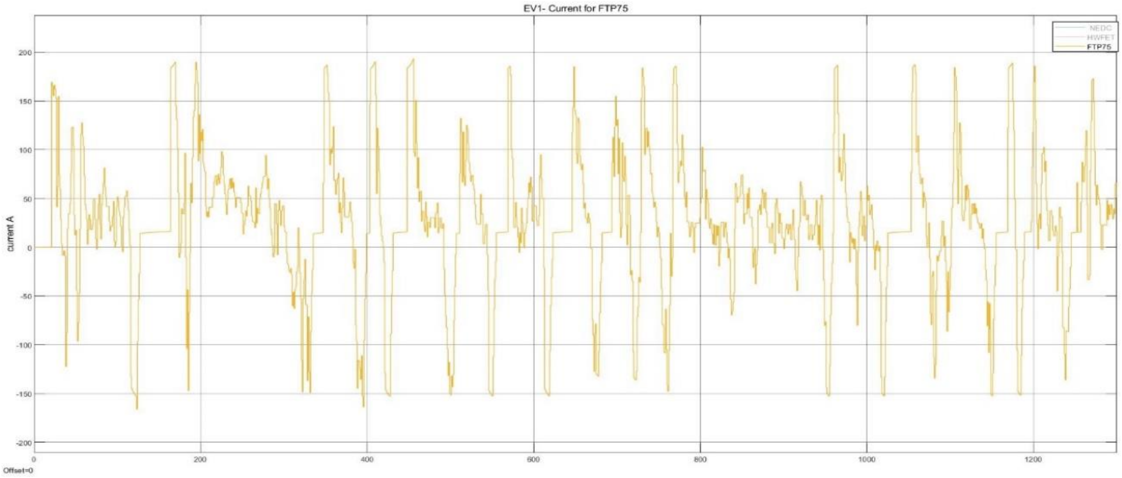


Figure 4.17 EV1 - Current for (FTP75)

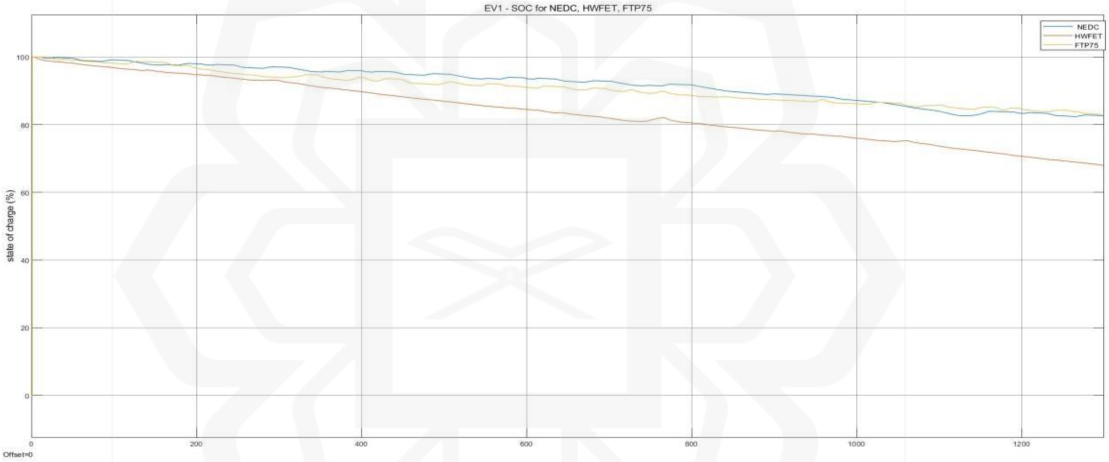


Figure 4.18 EV1 – SOC for (NEDC), (HWFET), (FTP75)

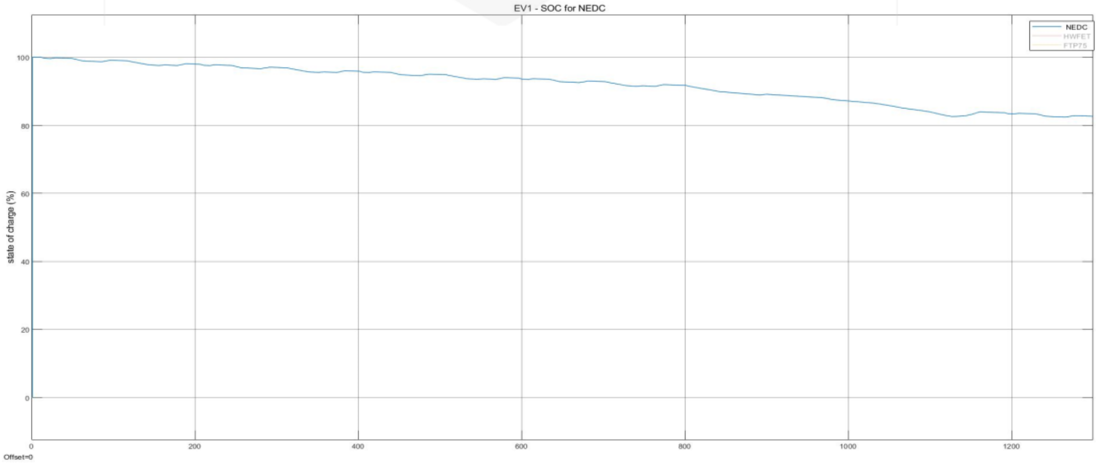


Figure 4.19 EV1 - SOC for (NEDC)

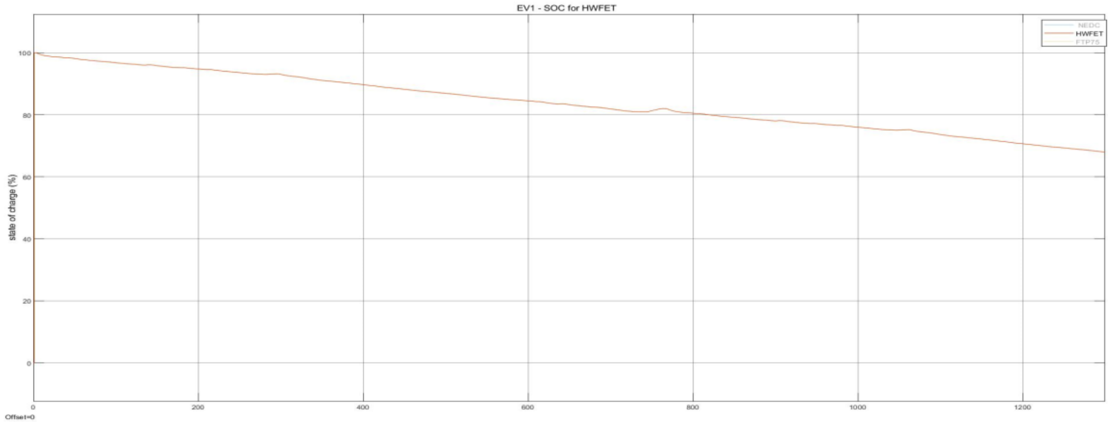


Figure 4.20 EV1 - SOC for (HWFET)

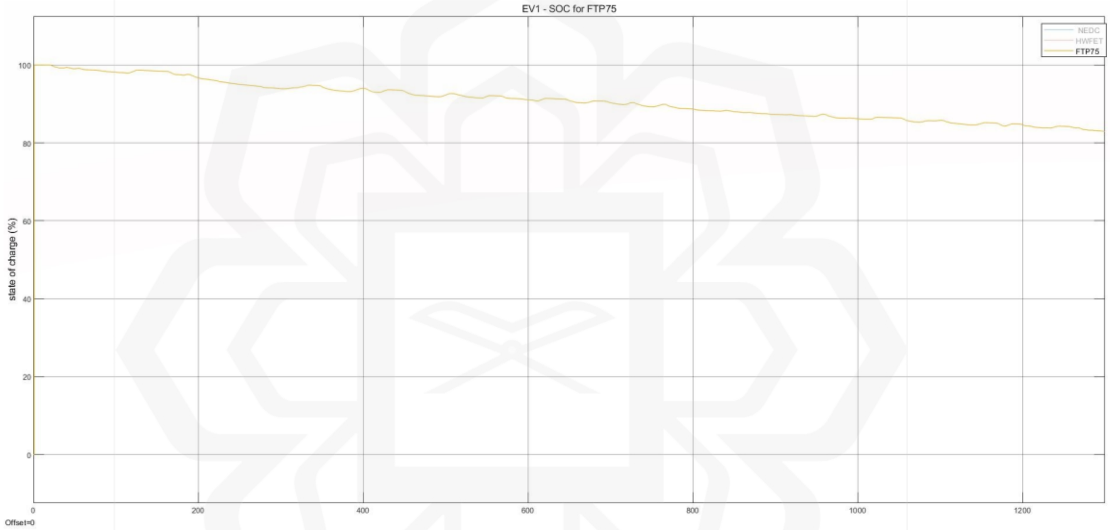


Figure 4.21 EV1 - SOC for (FTP75)

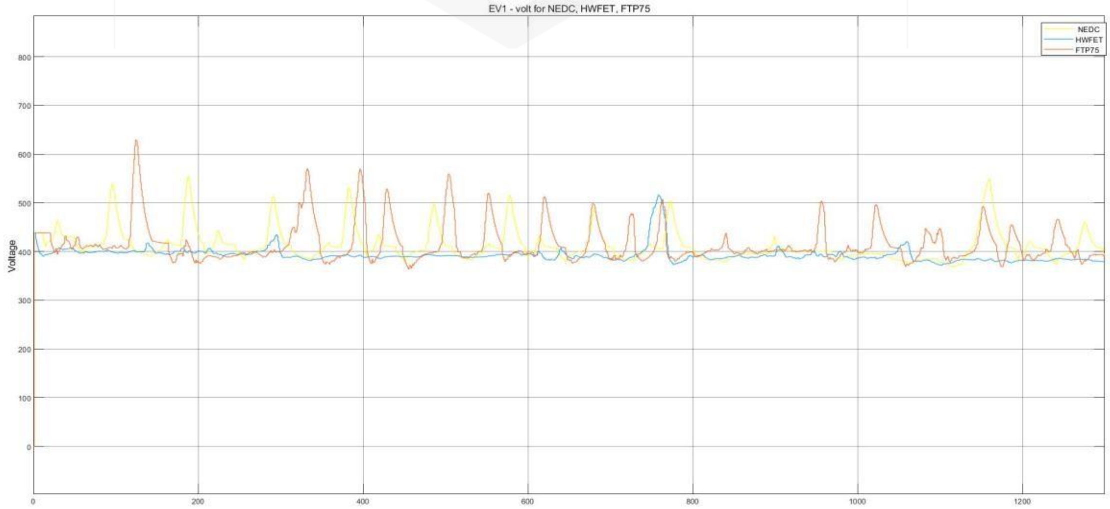


Figure 4.22 EV1 - voltages for (NEDC), (HWFET), and (FTP75)

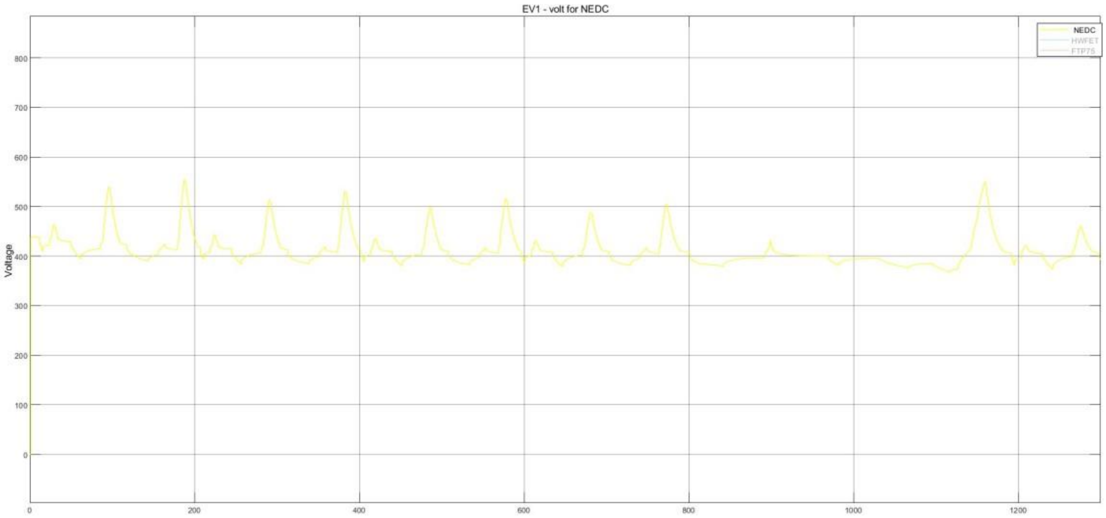


Figure 4.23 EV1 - voltages for (NEDC)

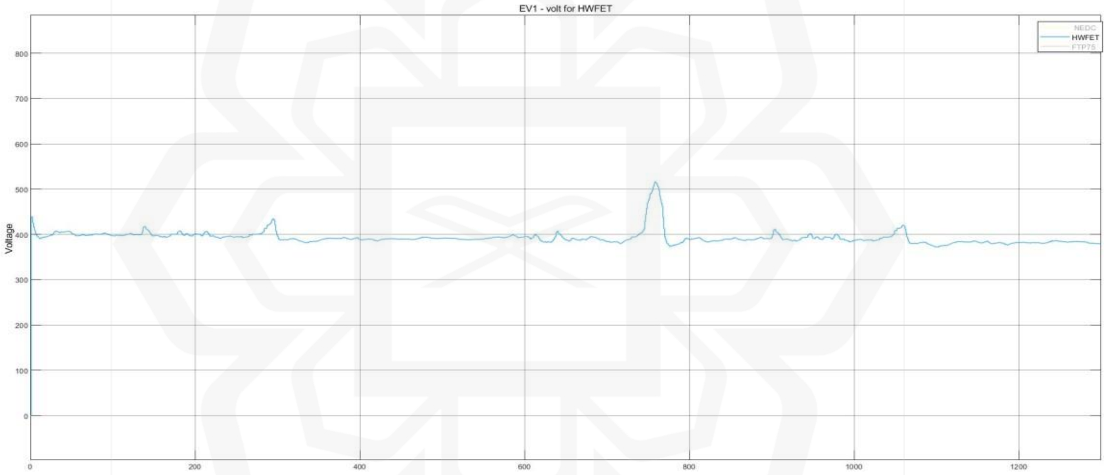


Figure 4.24 EV1 - voltages for (HWFET)

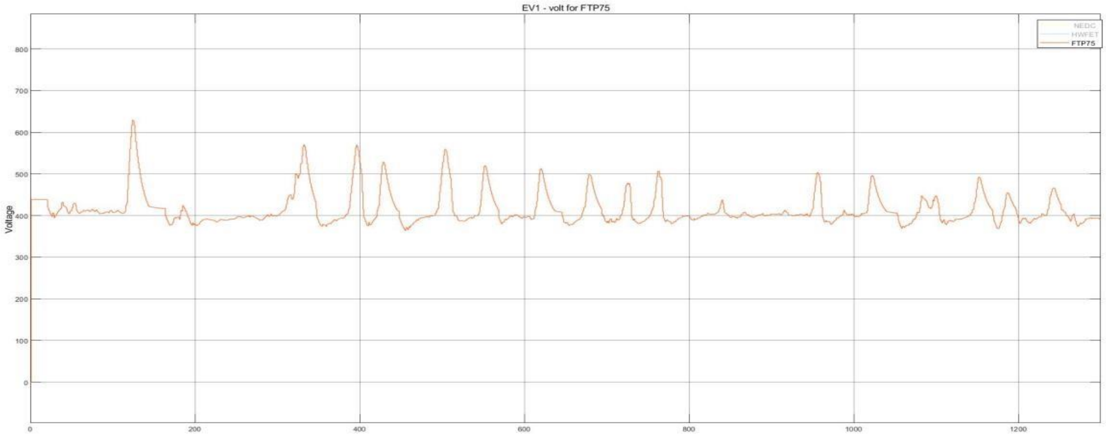


Figure 4.25 EV1 - voltages for (FTP75)

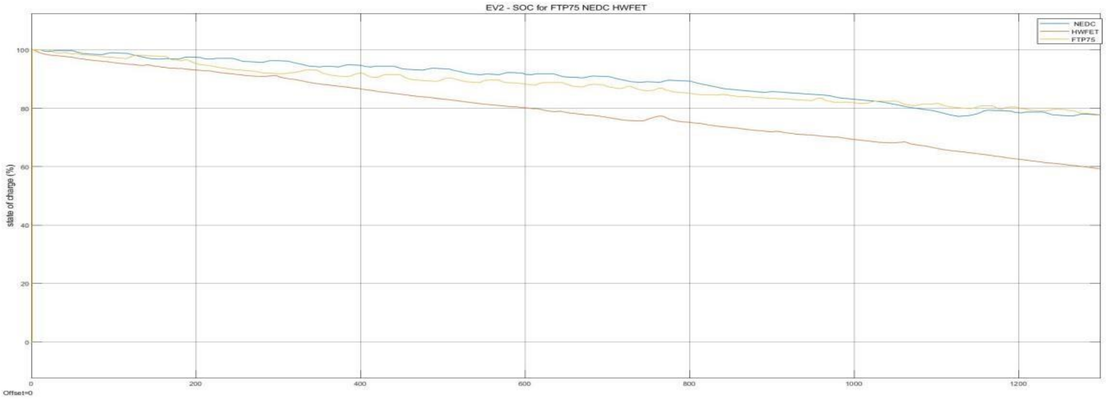


Figure 4.26 EV2 – SOC for (NEDC), (HWFET) and (FTP75)

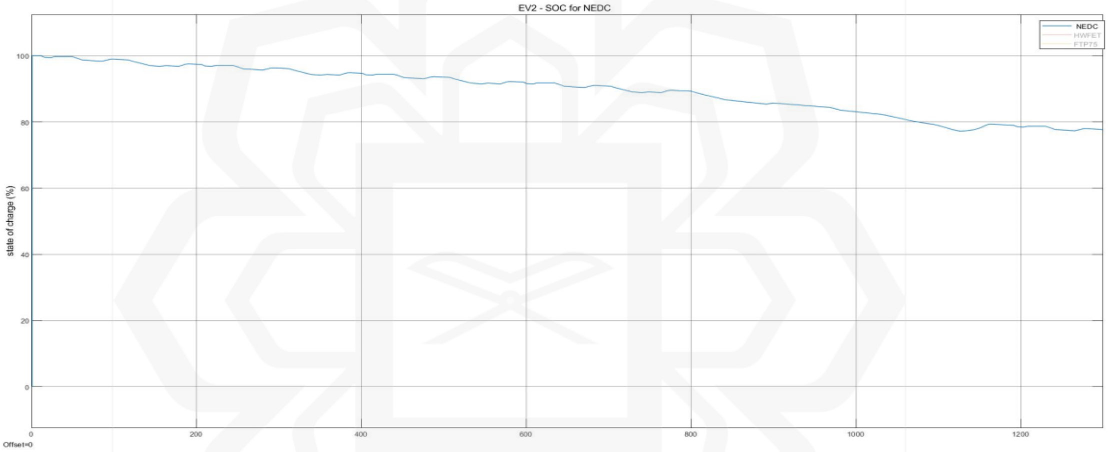


Figure 4.27 EV2 – SOC for (NEDC)

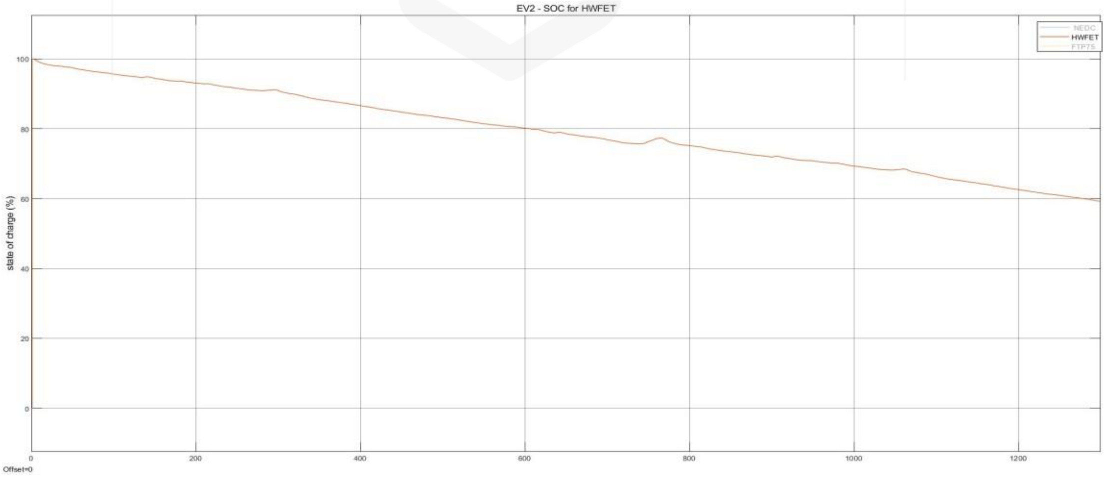


Figure 4.28 EV2 – SOC for (HWFET)

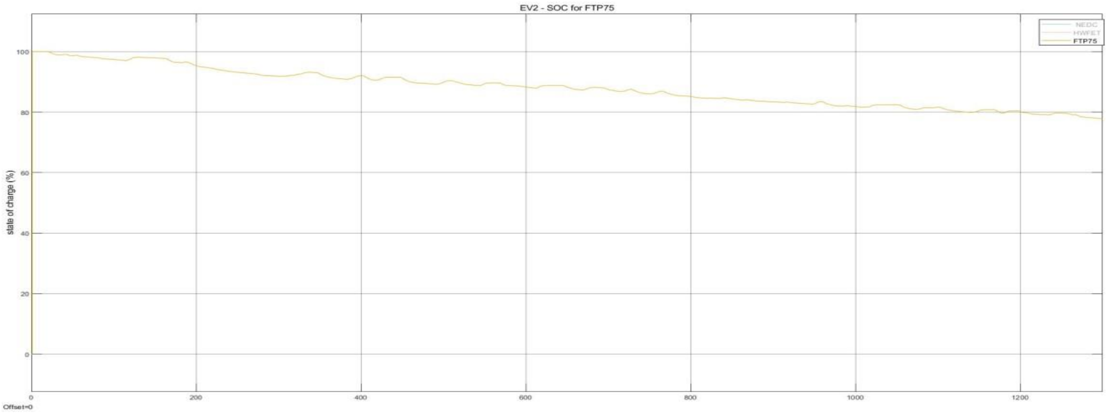


Figure 4.29 EV2 – SOC for (FTP75)

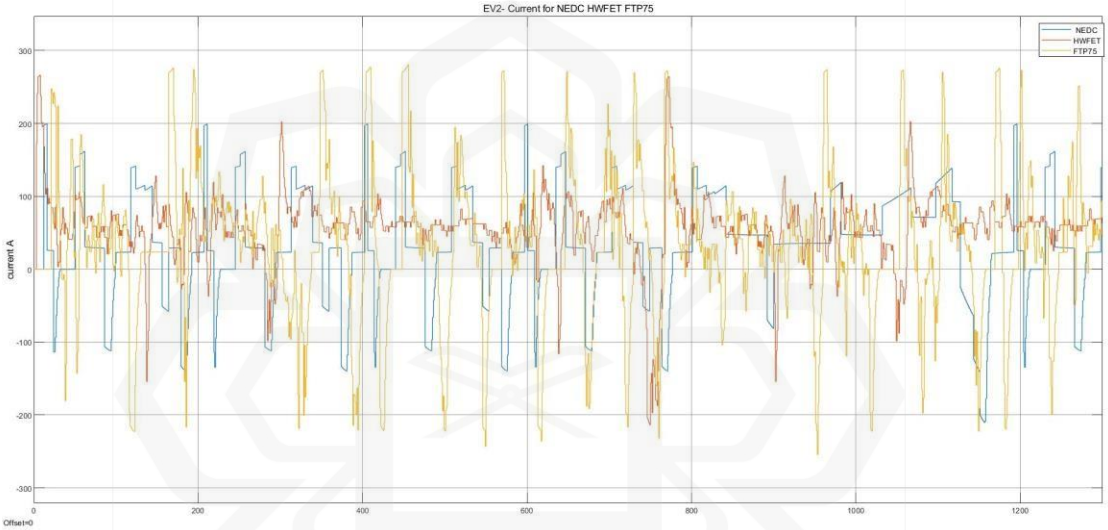


Figure 4.30 EV2 - Current for (NEDC), (HWFET) and (FTP75)

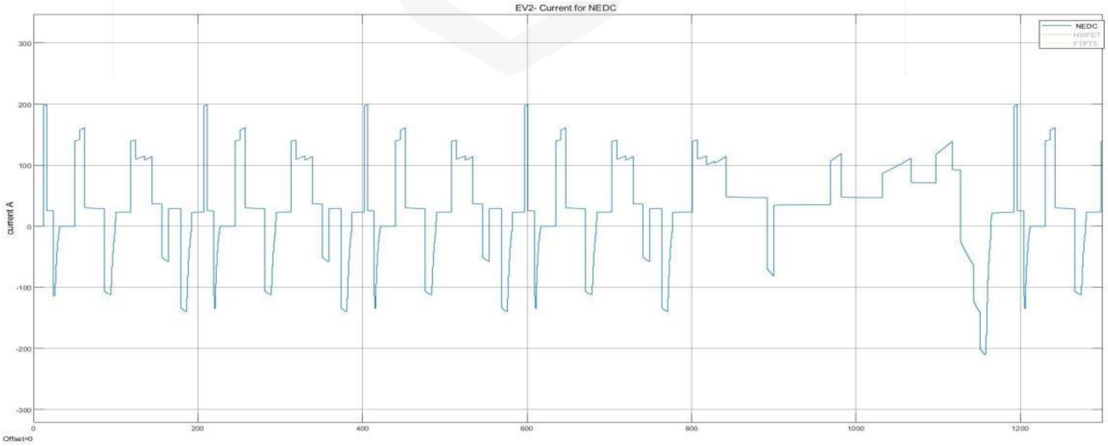


Figure 4.31 EV2 - Current for (NEDC)

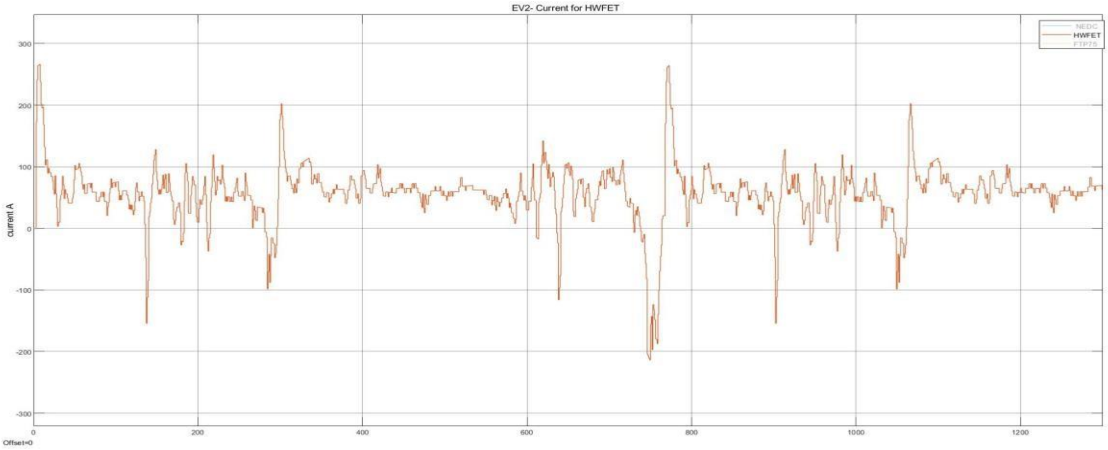


Figure 4.32 EV2 - Current for (HWFET)

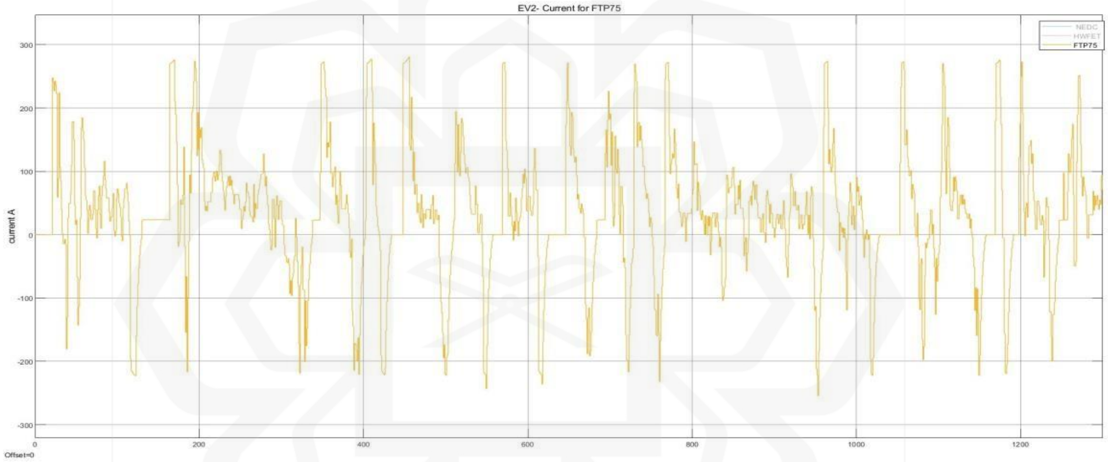


Figure 4.33 EV2 - Current for (FTP75)

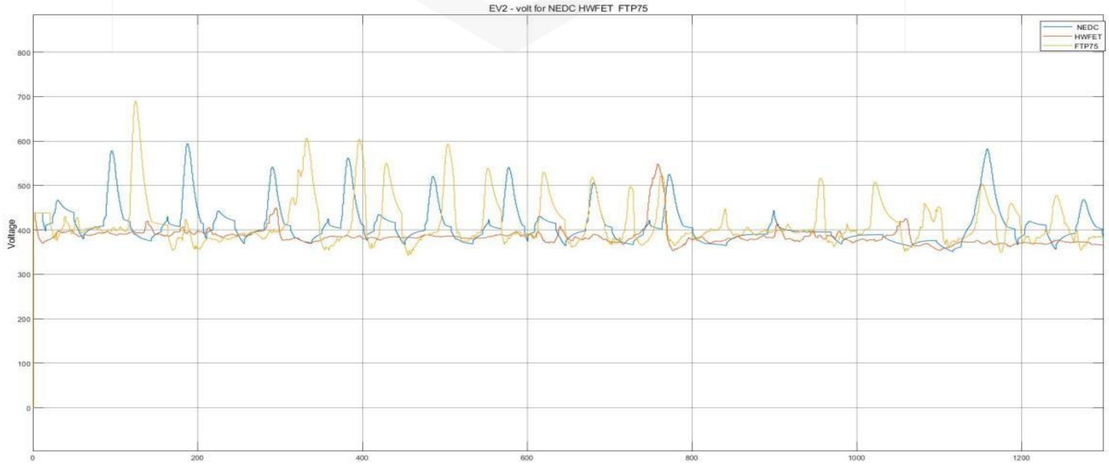


Figure 4.34 EV2 - Voltages for (NEDC), (HWFET), and (FTP75)

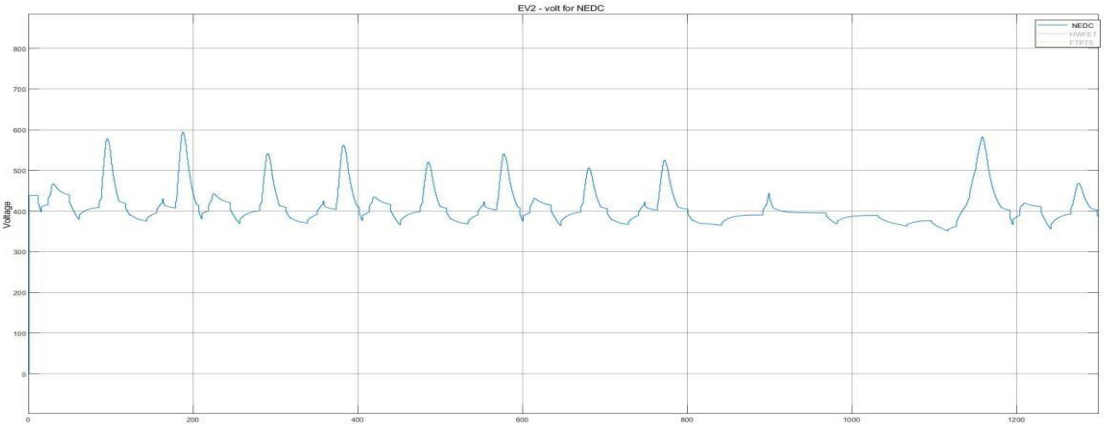


Figure 4.35 EV2 - Voltages for (NEDC)

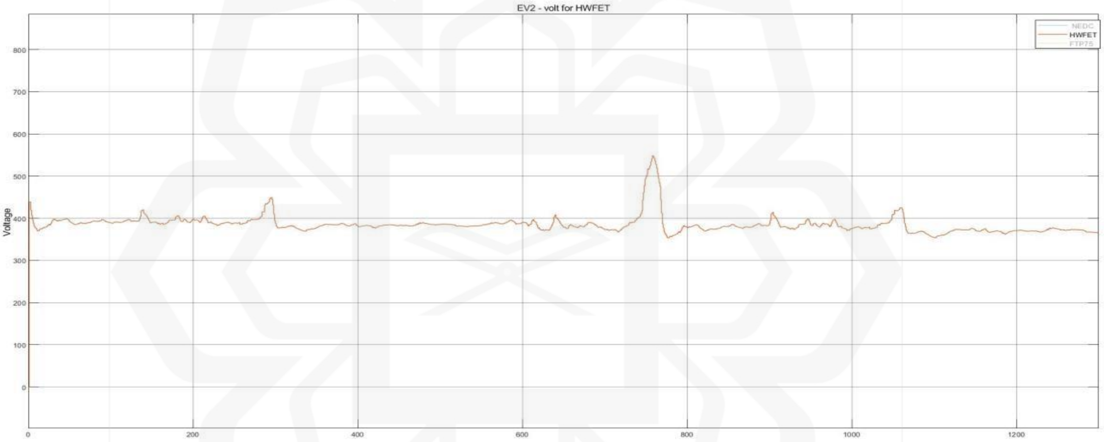


Figure 4.36 EV2 - Voltages for (HWFET)

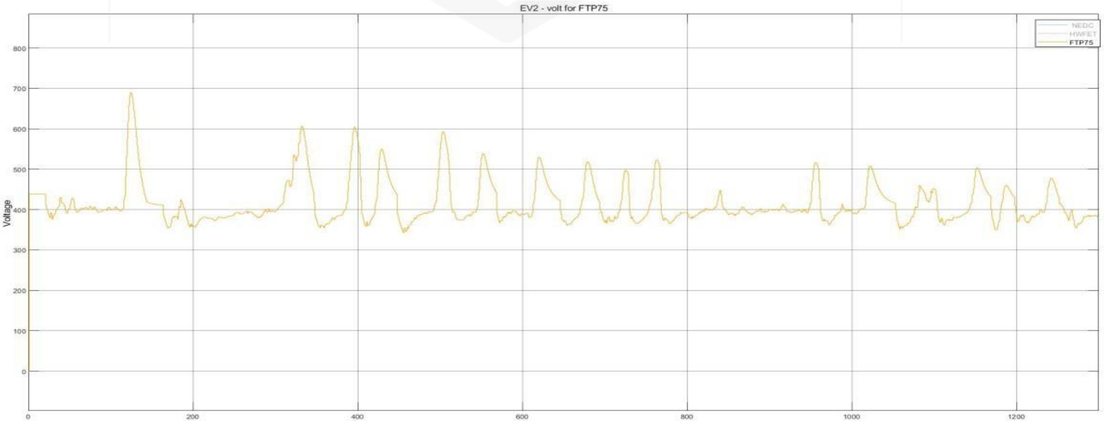


Figure 4.37 EV2 - Voltages for (FTP75)

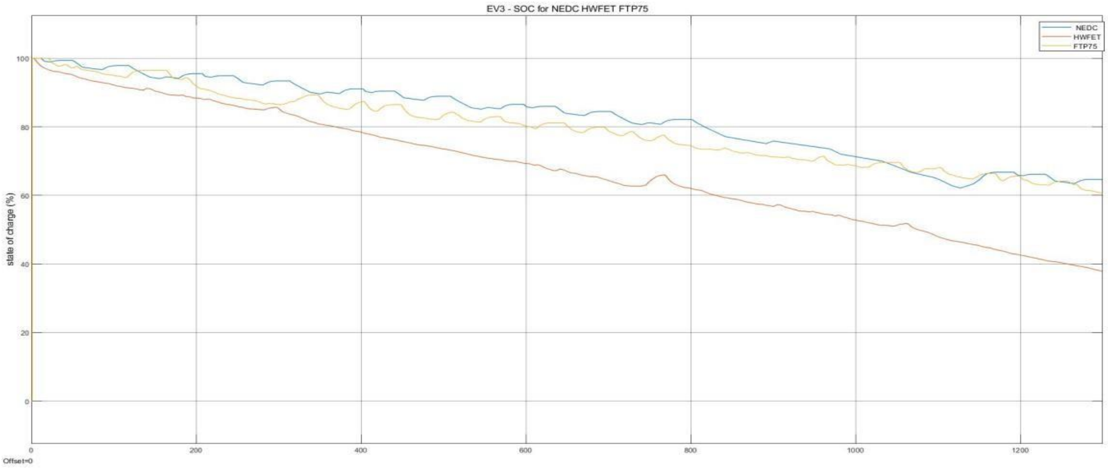


Figure 4.38 EV3 - SOC for (NEDC), (HWFET), and (FTP75)

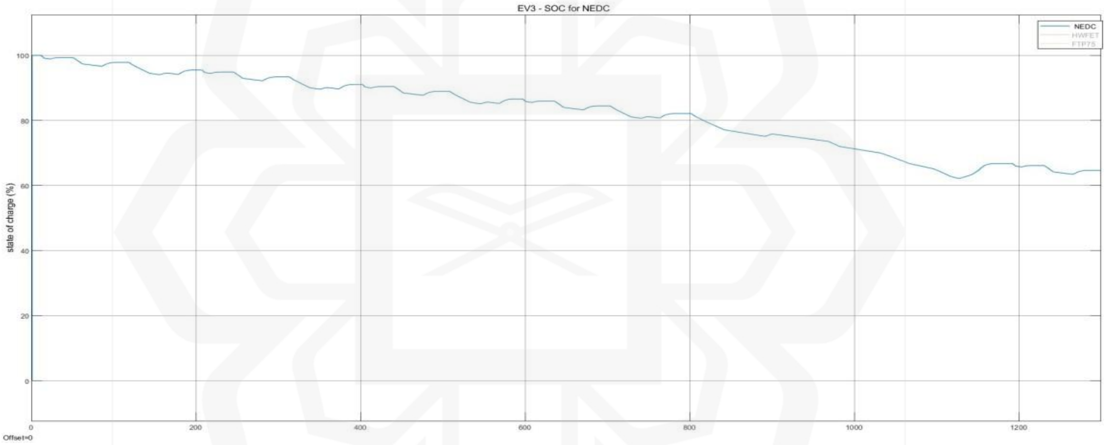


Figure 4.39 EV3 - SOC for (NEDC)

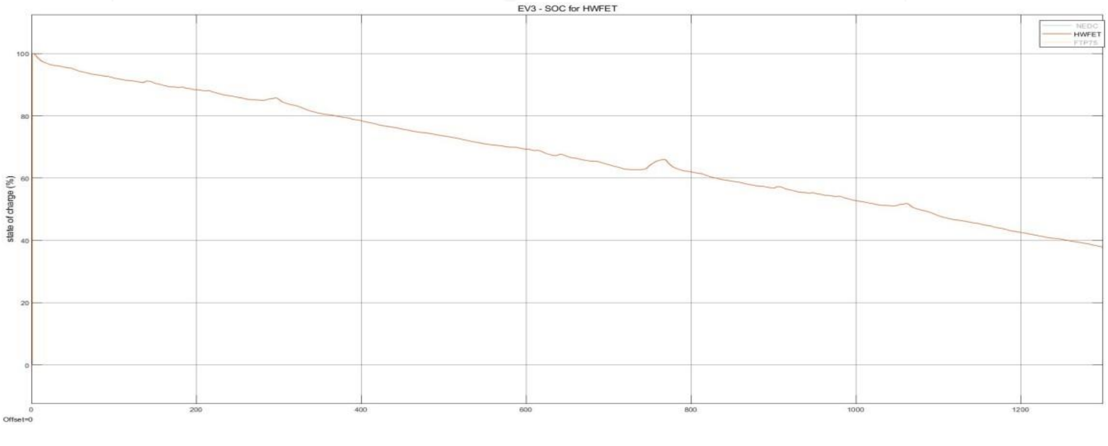


Figure 4.40 EV3 - SOC for (HWFET)

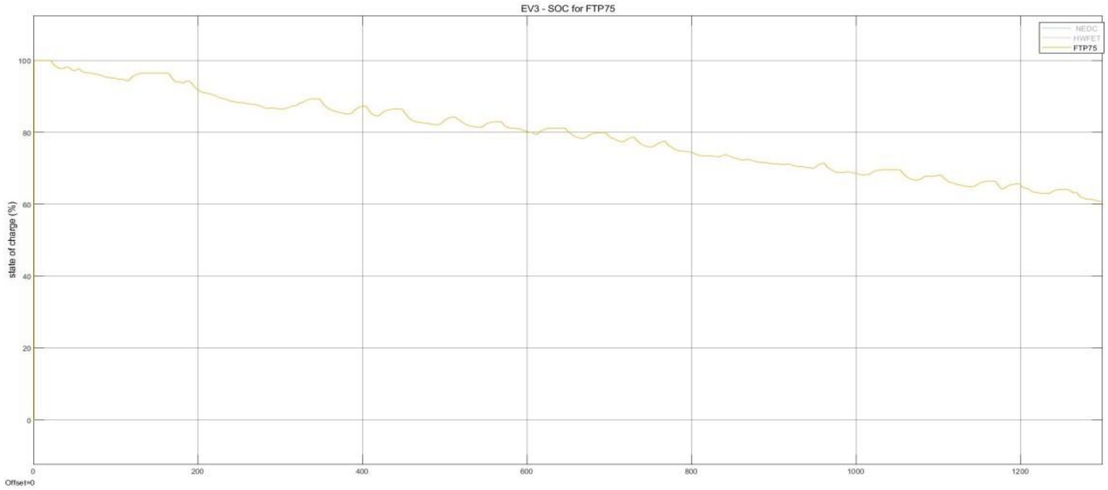


Figure 4.41 EV3 - SOC for (FTP75)

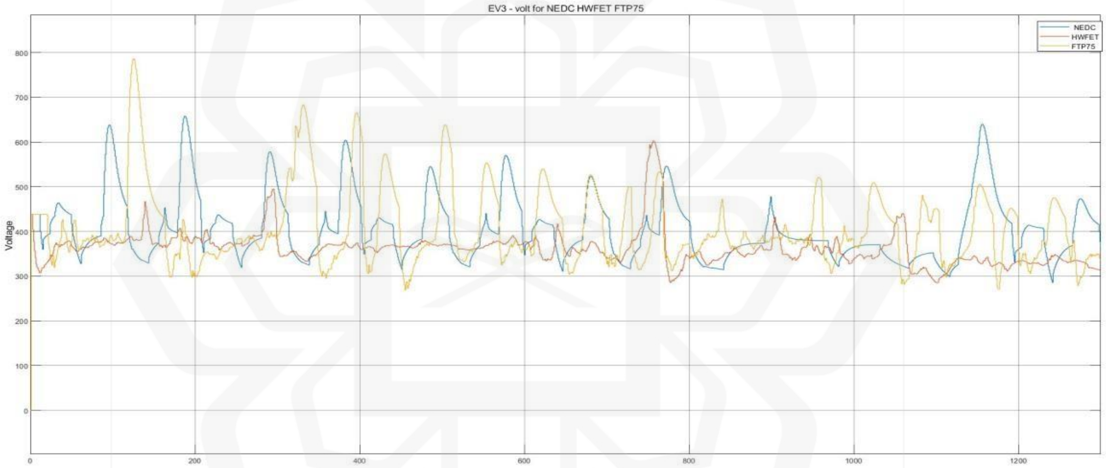


Figure 4.42 EV3 - voltage for (NEDC), (HWFET), and (FTP75)

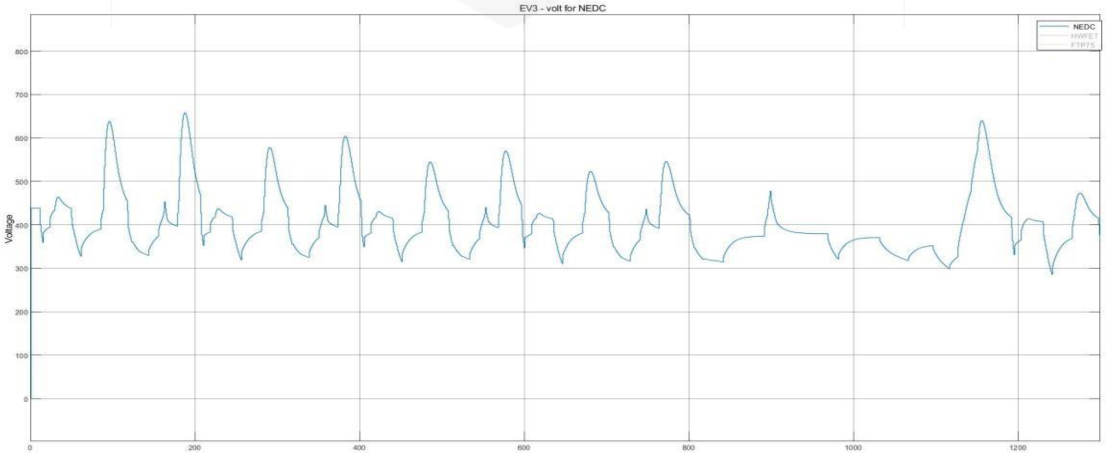


Figure 4.43 EV3 - voltage for (NEDC)

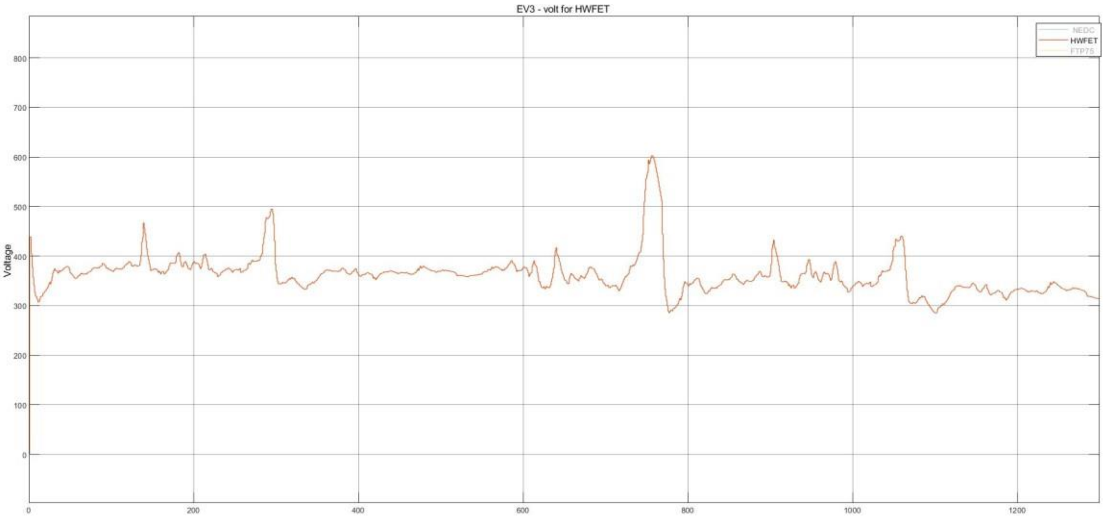


Figure 4.44 EV3 - voltage for (HWFET)

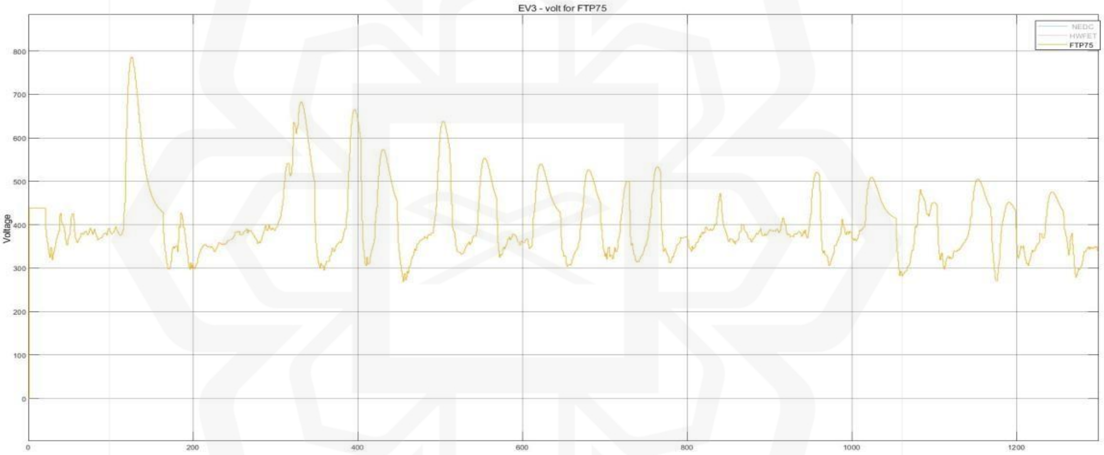


Figure 4.45 EV3 - voltage for (FTP75)

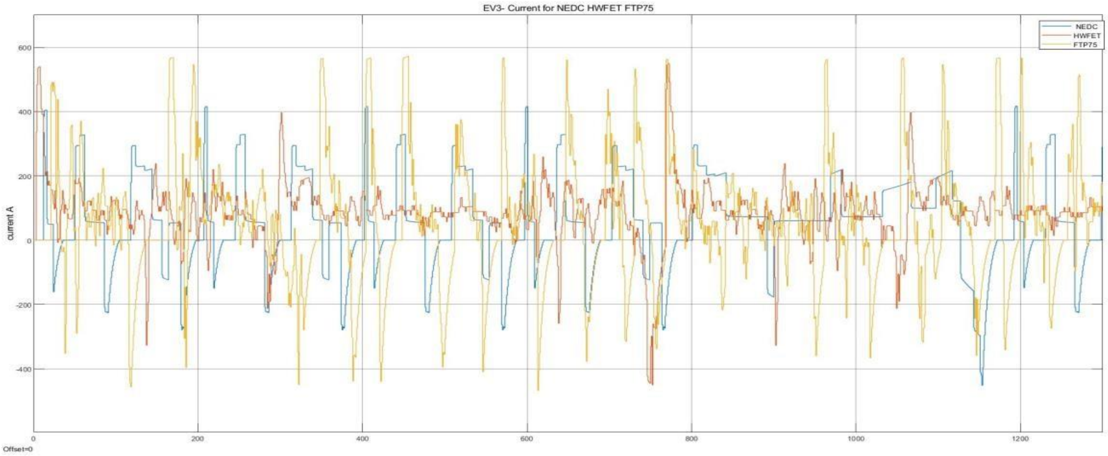


Figure 4.46 EV3 - Current for (NEDC), (HWFET) and (FTP75)

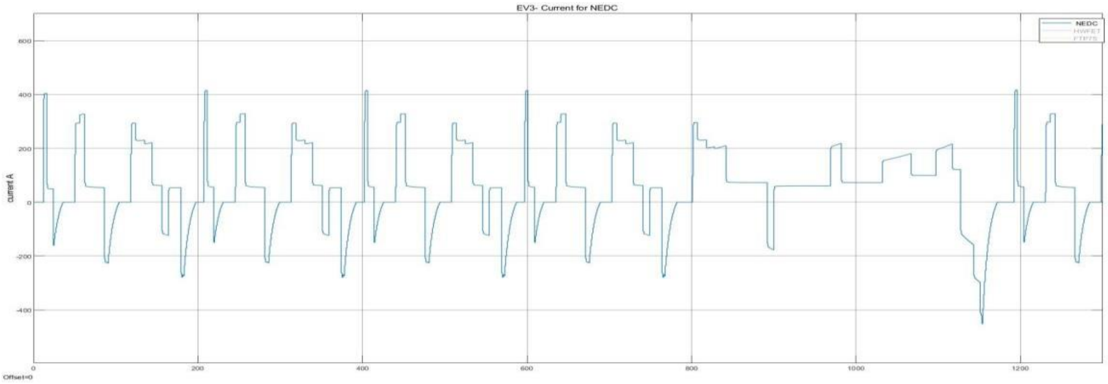


Figure 4.47 EV3 - Current for (NEDC)

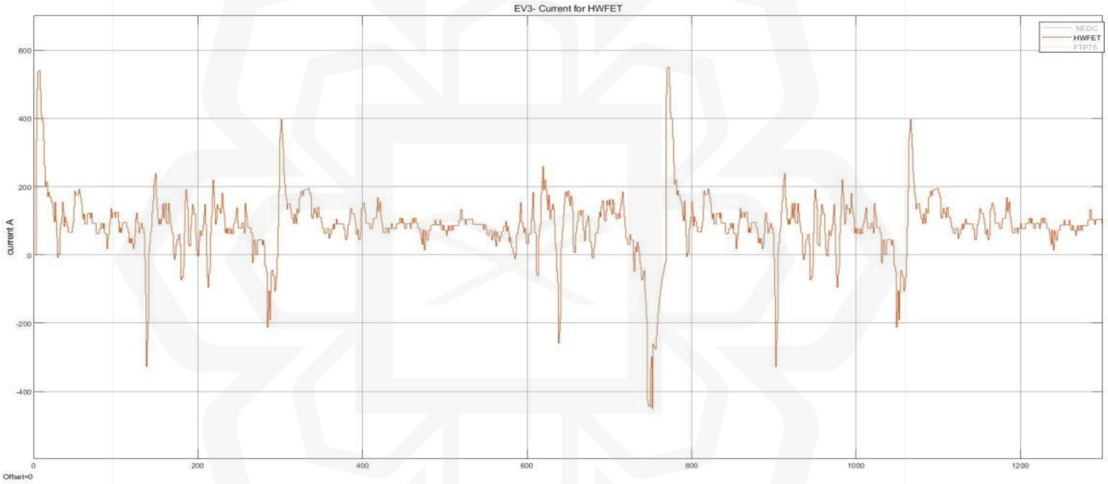


Figure 4.48 EV3 - Current for (HWFET)

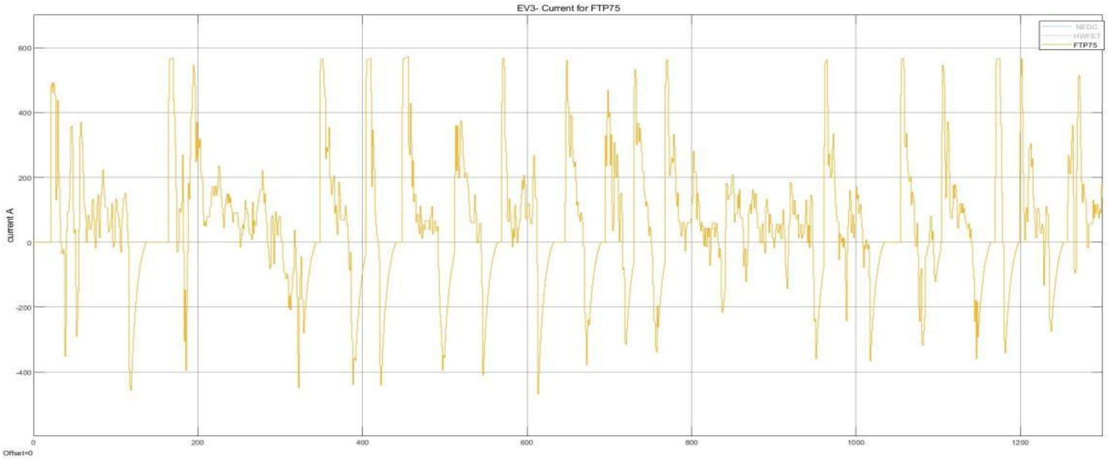


Figure 4.49 EV3 - Current for (FTP75

CHAPTER FIVE

CONCLUSION AND RECOMENDATION

This thesis has provided a thorough analysis of the energy vehicle components utilised in electric automobiles. The current varieties of totally electric vehicles are then presented. Additionally, in order to enhance performance metrics and lay the groundwork for future research, the paper thoroughly assesses and elaborates on a number of modelling approaches and methodologies, particularly when using the MATLAB Simulink tool, which is used for modelling and simulation of electric vehicles. In this thesis, the modelling and simulation of an electric vehicle (EV) using a DC motor drive system was covered. The EV range and performance under various operating situations have been predicted using the digital computer simulation tool MATLAB - Simulink, which has been designed and tested. The program's design makes it simple to specify and modify the key vehicle and drive system characteristics, which is especially helpful for conducting parametric studies. From a fully charged state until the batteries have been depleted to a set minimum voltage or until a defined state-of-charge SOC is reached; the software repeatedly mimics the procedure of a car over a speed versus time cycle. Each active component of the vehicle system is represented mathematically in the simulation. The simulation tool, which was created to simulate how a vehicle and its drive system would function under SAE standard driving conditions, has proved helpful in the study and design of vehicle drive control systems. The first step in creating an accurate electric vehicle model is to choose the right parameters and comprehend their properties. This thesis described a research of vehicle characteristics based on an electric vehicle simulation. It is suggested that three separate automobile segments be used to simulate three driving cycles. Additionally, we provided the same battery capacity for various electric car model segment specifications. The study has conceptually demonstrated that to enable for fuel savings, an electric vehicle type must've been small and lightweight sufficient. Performances and energy consumption are better in smaller automobile classes. However, compact electric vehicles with lesser battery capacities are highly suggested for urban commuting owing to weight and space restrictions since they might benefit from the regenerative braking mode. To increase the battery's lifespan, a higher-class automobile that consumes more energy should drive on the highway with a discharge profile that isless fluctuant. Traditional segmentation (i.e., by dimension) is completely inadequate for electric vehicles; because to their traction batteries, compact EVs may function more quickly and have a longer range than huge EVs. Therefore, the range and peak speed of an electric vehicle should be used to segment it. With upcoming work, it is suggested to include price and overall performance as design requirements. Additionally, it is advised to look at ways to minimise the loss brought on by auxiliary loads. Moreover, academics nowadays are paying increasingly more attention to two other important factors: motor control and energy management techniques.

REFERENCES

Abulifa, A. A., Raja Ahmad, R. K., Che Soh, A., Radzi, M. A. M., & Hassan, M. K. (2018). Modelling and simulation of battery electric vehicle by using MATLAB-Simulink. *IEEE Student Conference on Research and Development: Inspiring Technology for Humanity, SCOReD 2017 - Proceedings, 2018-Janua,*383–387.

Babangida, A., & Szemes, P. T. (2021). Electric Vehicle Modelling and Simulation of a Light Commercial Vehicle Using PMSM Propulsion. *Hungarian Journal of Industry and Chemistry*, *49*(1), 37–46.

Basu, A. K., S. Tatiya and S. Bhattacharya (2019). Overview of electric vehicles (EVs) and EV sensors. Sensors for Automotive and Aerospace Applications,Springer: 107-122.

Basu, A.K., S. Tatiya, and S. Bhattacharya, *Overview of electric vehicles (EVs) and EV sensors*, in *Sensors for Automotive and Aerospace Applications*. 2019, Springer. p. 107-122.

Bilgin, B. and A. Sathyan, *Fundamentals of electric machines.* Advanced electric drive vehicles, 2014: p. 107-186.

Bitar, Z., S. Al Jabi, and I. Khamis, Modeling and simulation of series DC motors in electric car. Energy Procedia, 2014. 50: p. 460-470.

C. (2017). Electric vehicle drivetrain optimisation. *IET Electrical Systems in Transportation*, *7*(1), 32–40.

Campagna, N., Castiglia, V., Miceli, R., Mastromauro, R. A., Spataro, C., Trapanese, M., & Viola, F. (2020). Battery models for battery powered applications: A comparative study. *Energies*, *13*(15).

Chau, K. (2014). Pure electric vehicles. Alternative fuels and advanced vehicle technologies for improved environmental performance, Elsevier: 655-684.

Chau, K. (2014). Pure electric vehicles. Alternative fuels and advanced vehicle technologies for improved environmental performance, Elsevier: 655-684.

Chau, K. and Z. Wang (2005). "Overview of power electronic drives for electric vehicles." HAIT Journal of Science and Engineering-B: Applied Sciences and Engineering 2(5-6): 737-761.

Das, S., *Modeling for Hybrid and Electric Vehicles Using Simscape.* Synthesis Lectures on Advances in Automotive Technology, 2021. **5**(1): p. 1-217.

Eckert, J. J., Silva, L. C. A., Costa, E. S., Santiciolli, F. M., Dedini, F. G., & Corrêa, F.

Ehsani, M., Y. Gao, and J.M. Miller, Hybrid Electric Vehicles: Architecture and Motor

Drives. Proceedings of the IEEE, 2007. 95(4): p. 719-728.

Eldho Aliasand, A. and F. T. Josh (2020). "Selection of Motor foran Electric Vehicle: A Review." Materials Today: Proceedings 24: 1804-1815.

Fadul, S. M. E., Aris, I. B., Misron, N., Halin, I. A., & Iqbal, A. K. M. (2018). Modelling and Simulation of Powertrain System for Electric Car. *Journal of the Society of Automotive Engineers Malaysia*, *2*(1), 23–34. Retrieved from www.journal.saemalaysia.org.my

Fan, H., *Modelling and simulation of an electric vehicle with battery-powered induction motor drive system.* 1994.

Goodarzi, G.A.H., John G, <*Goodarzi, Gordon A._ Hayes, John G - Electric powertrain _ energy systems, power electronics & drives for hybrid, electric & fuel cell vehicles (2018, John Wiley & Sons) - libgen.lc.pdf*>. 2018.

Goodarzi, G.A.H., John G, <Goodarzi, Gordon A._ Hayes, John G - Electric powertrain_ energy systems, power electronics & drives for hybrid, electric & fuel cell vehicles (2018, John Wiley & Sons) - libgen.lc.pdf>. 2018.

Hadboul, R. M., & Ali, D. A. M. (2021). Modeling, Simulation and Analysis of Electric Vehicle Driven by Induction Motor. *IOP Conference Series: Materials Science and Engineering*, *1105*(1), 012022.

Hamut, H.S., N. Javani, and I. Dinçer, *Thermal management of electric vehicle battery systems*. 2016: John Wiley & Sons.

Hashemnia, N., & Asaei, B. (2008). Comparative study of using different electric motors in the electric vehicles. *Proceedings of the 2008 International Conference on Electrical Machines, ICEM'08*, (c), 5–9.

Hofman, T., & Dai, C. H. (2010). Energy efficiency analysis and comparison of transmission technologies for an electric vehicle. *2010 IEEE Vehicle Power and Propulsion Conference, VPPC 2010*.

Husain, I., & Islam, M. S. (1999). Design, modeling and simulation of an electric vehicle system. *SAE Technical Papers*, (November).

Jaafar, A.H. and A. Rahman, EMA-CVT Performance for UDDS and HWFET Cycles with Fuzzy Logic Approach. TEST Engineering & Management, 2020. 83: p. 13775-13781.

Janiaud, N., Vallet, F. X., Petit, M., & Sandou, G. (2010). Electric vehicle powertrain simulation to optimize battery and vehicle performances. *2010 IEEE Vehicle Power and Propulsion Conference, VPPC 2010.*

Kasoju bharath kumar. (2020). Simulation of Electric Vehicle Drive with Matlab/Simulink. *International Journal of Advances in Engineering and Management*, *2*(2), 652–654.

Kaushik, S. (2019). Modeling and simulation of electric vehicle to optimize its cost and range. *International Journal of Engineering and Advanced Technology*, *8*(6), 415–419.

Khandaker, M., *Modeling, simulation, and analysis of series hybrid electric vehicles for fuel economy improvement*. 2011: Wayne State University.

Kıyaklı, A. O., & Solmaz, H. (2019). Modeling of an Electric Vehicle with MATLAB/Simulink. *International Journal of Automotive Science And Technology*, (January), 9–15.

Konstantas, G. and A. Stamatelos, Quality assurance of exhaust emissions test data. Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, 2004. 218(8): p. 901-914.

Larminie, J. and J. Lowry, *Electric vehicle technology explained*. 2012: John Wiley & Sons.

Lee, J. M., & Cho, B. H. (1997). Modeling and simulation of electric vehicle power system. *Proceedings of the Intersociety Energy Conversion Engineering Conference*, *3–4*, 2005–2010.

Maaz Mufti, G., Ur Rehman, M., & Abdul Basit, D. (2018). Modelling and Simulation of the Electrical Vehicle Using Matlab and Verifying it by Driving Cycles. *International Journal of Engineering & Technology*, *7*(4.38), 871.

Miri, I., A. Fotouhi and N. Ewin (2021). "Electric vehicle energy consumption modelling and estimation—A case study." International Journal of Energy Research 45(1): 501-520.

Mohd, T. A. T., Hassan, M. K., Aris, I., Che Soh, A., Ibrahim, B. S. K. K., & Hat, M.K. (2015). Simulation based study of electric vehicle parameters. *ARPN Journal of Engineering and Applied Sciences*, *10*(19), 8541–8546.study

Mohd, T., M. Hassan, I. Aris, A. C. Soh, B. Ibrahim and M. Hat (2015). "Simulation based study of electric vehicle parameters." ARPN Journal of Engineering and Applied Sciences 10(19): 8541-8546.

Moldovanu, D. (2020). Implementation in MATLAB Simulink of a basic electric vehicle. *IOP Conference Series: Materials Science and Engineering*, *898*(1).

Morsy, N., C.-Á. José Pablo, M. Gaber and Á. Sánchez-Miralles (2020). "Review of Positive and Negative Impacts of Electric Vehicles Charging on Electric Power Systems." Energies 13(18): 4675.

Mousavi G., S. M., & Nikdel, M. (2014). Various battery models for various simulation studies and applications. *Renewable and Sustainable Energy Reviews*, *32*, 477–485.

Oral Vatan. (2011). *Modelling And Simulation of Longitudinal Dynamics of Electric Vehicles*. İstanbul Technical University Institute Of Science And Technology.

Rajashekara, K. (2013). "Present status and future trends in electric vehicle propulsion technologies." IEEE journal of emerging and selected topics in power electronics 1(1): 3-10.

S, L. and L. P. P.S (2019). "Mathematical modeling of Electric vehicles - A survey." Control Engineering Practice 92: 104138.

Salameh, M. (2020). Integrated Design Framework for Electric Motor Drive Systems. 27956385 Ph.D., Illinois Institute of Technology.

Sarathkumar, T. V., Poornanand, M., & Goswami, A. K. (2020). Modelling and simulation of electric vehicle drive through SAEJ227 EUDC cycles. *2020 IEEE Students' Conference on Engineering and Systems, SCES 2020*.

Schaltz, E. and S. Soylu, *Electrical vehicle design and modeling.* Electric vehicles-modelling and simulations, 2011. **1**: p. 1-24.

Scrosati, B., J. Garche and W. Tillmetz (2015). Advances in battery technologies for electric vehicles, Woodhead Publishing.

Sen, C., Performance analysis of batteries used in electric and hybrid electric vehicles. 2010.48.

Shah, R. R. (2021). Modelling and performance analysis of electric vehicle. *International Journal of Ambient Energy*.

Sharmila, B., Srinivasan, K., Devasena, D., Suresh, M., Panchal, H., Ashokkumar, R.,

Slough, J., Belcher, M., Tsui, T., & Bhattacharya, S. (2021). Modeling and Simulation of Electric Vehicles Using Simulink and Simscape. *IEEE Vehicular Technology Conference*, *2021-Septe*, 8–13.

Sun, J., *Electric and Hybrid Vehicle: Simulation and Control*. 1997, University of Hawai'i at Manoa: Ann Arbor. p. 92.

Terras, J. M. d. F., A. Neves, D. M. Sousa and A. Roque (2010). Modelling and simulation of a commercial electric vehicle. 13th International IEEE Conference on Intelligent Transportation Systems.

Terras, J. M., Neves, A., Sousa, D. M., & Roque, A. (2010). Estimation of the induction motor parameters of an electric vehicle. *2010 IEEE Vehicle Power and Propulsion Conference, VPPC 2010*, 0–5.

Tóth-Nagy, C., Investigation and simulation of the planetary combination hybrid electric vehicle. 2000: West Virginia University

Un-Noor, F., et al., A comprehensive study of key electric vehicle (EV) components, technologies, challenges, impacts, and future direction of development. Energies, 2017. 10(8): p. 1217.

Urazel, B., & Keskin, K. (2020). Electric Drive Vehicle Model and Simulation with Matlab. *Journal of the Institute of Science and Technology*, *10*(4), 2461–2473.

Vempalli, S. K., Ramprabhakar, J., Shankar, S., & Prabhakar, G. (2018). Electric Vehicle Designing, Modelling and Simulation. *2018 4th International Conference for Convergence in Technology, I2CT 2018*, 1–6.

Vidyanandan, K. V. (2019). Batteries for Electric Vehicles. *New Materials & New Processes*, *2*(November), 362–364.

Wang, W. L., W. Z. Liu, B. Q. Tao and J. W. Ma (2014). "Parameter Design and Simulation Research of Power System for Electric Vehicle." Applied Mechanics and Materials 496-500: 969-973.

Xue, X. D., Cheng, K. W. E., & Cheung, N. C. (2008). Selection of electric motor drives for electric vehicles. *2008 Australasian Universities Power Engineering Conference, AUPEC 2008*, 1–6.

Yenigala, T. (2017). *Battery Storage Performance Analysis Using Multiphysics Simulation Through Application Builder and Data Analytics*. Northern Illinois University

Yildiz, A.B., Electrical equivalent circuit-based modeling and analysis of direct current motors. International Journal of Electrical Power & Energy Systems, 2012. 43(1): p. 1043-1047.

Young, K., C. Wang and K. Strunz (2013). Electric vehicle battery technologies. Electric vehicle integration into modern power networks, Springer: 15-56.

Young, K., C. Wang, and K. Strunz, *Electric vehicle battery technologies*, in *Electric vehicle integration into modern power networks*. 2013, Springer. p. 15-56.

Zervas, E., Impact of altitude on fuel consumption of a gasoline passenger car. Fuel, 2011. 90: p. 2340-2342.

Zhou, J., Shen, X., & Liu, D. (2014). Modeling and simulation for electric vehicle powertrain controls. *IEEE Transportation Electrification Conference and Expo, ITEC Asia-Pacific 2014 - Conference Proceedings*, *1*, 3–6.