Sizing Estimation of Battery and Motor for Electrical Vechile Application at Different Drive Cycles

I Narasimha Swamy[1], Ch. Gayathri[2], Y. Bhargav Teja[3], K. Sai Charan[4]

[1]Assistant Professor, Department of Electrical and Electronics Engineering, MVSR Engineering College, Hyderabad
[2,3,4]BE, IV Year, Department of Electrical and Electronics Engineering, MVSR Engineering College, Hyderabad

Abstract
As the automotive industry transitions towards electrification, the efficient design and sizing of electric vehicle (EV) components, specifically motors and batteries, have become critical for achieving optimal performance and range. This simulation project aims to develop a comprehensive framework for sizing the motor and battery systems of electric vehicles through the utilization of advanced simulation tools and optimization techniques. This article aims to develop such a system and test it with standard drive cycles to establish the appropriate motor specifications and battery configuration for the drive cycle to be meet efficient and high-caliber performance. This model incorporates factors such as vehicle mass, aerodynamics, road load, and efficiency characteristics of the electric powertrain components by considering both mechanical and electrical factors, and an analytical model for an EV powertrain has been built to show vehicular dynamics.

Keywords: Electric Vehicle, Bridge Converter, Battery, Drive Cycle, SOC

1. Introduction

As the automotive landscape undergoes a transformative shift, this delves into the core of EV technology. From battery advancements to sustainable mobility solutions, we unravel the complexities of electric propulsion, offering insights into the environmental benefits, challenges, and the electrifying potential that shapes our road ahead. On this revolutionary journey into the future of transportation our exploration of electric vehicles (EVs) began[1].

Electric vehicles (EVs) represent a transformative solution to global challenges such as pollution, fossil fuel depletion, and climate change. They offer quiet operation, zero emissions, and lower maintenance costs. While the concept of electric propulsion dates to the 19th century, recent years have seen a surge in EV popularity due to advances in battery technology, declining costs, and increased awareness of their benefits. At the core of every EV is a sophisticated battery pack composed of lithium-ion cells, providing power to electric motors known for their instant torque delivery and energy efficiency. Power electronics components regulate electricity flow, while advanced software ensures optimal performance and safety[2]-[3].

In the Electric Vehicle applications, different types of batteries have been used. Estimating parameters like State of Charge, Battery Temperature, Battery Current are crucial in understanding battery performance. Since the cost of the Battery is a major Factor in electric vehicles, ensuring good performance & efficient charging is vital. Managing the battery system becomes more effective when accurate estimation of the State of charge (SOC) is possible. Even with the estimation of motor parameters as motor power, torque etc., plays a major role in meeting the driving requirements as speed, distance travelled and vehicle load[4].

1.1 Challenges

Lack of Comprehensive Charging Infrastructure: One of the main obstacles for EV adoption is the limited availability of charging stations. A comprehensive and accessible charging infrastructure is crucial to alleviate "range anxiety" and encourage widespread EV use. Without a robust network of charging points, users may hesitate to switch to electric vehicles due to concerns about running out of battery power during longer trips[5].

Selection of Power Conductors: Choosing the right power conductors (wires and cables) is essential for efficient power transmission within an EV. High-voltage systems require specialized conductors that can handle the current without excessive losses or overheating. Designers must balance conductivity, weight, and cost[6].

Driving Range: While EVs have made significant progress in range, achieving a comparable driving range to traditional gasoline-powered vehicles remains a challenge. Battery technology improvements and efficient power management are essential to extend the driving range of EVs.

1.2 Problem statement

The sizing estimation of the battery and motor of an electric vehicle is a complex and multi-faceted problem that requires consideration of various factors such as vehicle weight, aerodynamics, driving patterns, temperature, and energy efficiency. The goal is to find the optimal combination of battery capacity and motor power output to meet the performance requirements of the vehicle while maximizing range and efficiency. The sizing estimation of the battery and motor is crucial for achieving the desired performance, range, and efficiency of an electric vehicle. It requires a thorough understanding of the vehicle's operational requirements and careful consideration of various factors to ensure optimal performance and customer satisfaction

1.3 Objective

The primary objective is to optimize the EV’s driving range. By analysing the specific drive cycle (representing speed and acceleration patterns) and estimating energy consumption.

2. Proposed Work

The electric vehicle powertrain serves as the beating heart of the EV revolution, seamlessly converting electrical energy into propulsive force. The powertrain of an electric vehicle (EV) is a critical component that includes all the parts involved in generating power and transferring it to the wheels to propel the vehicle. EV powertrain comprises components like the battery, electric motor, power electronics along with additional hardware and software elements. Electronic Control Units (ECUs) facilitate data exchange and processing, ensuring efficient, sustainable, and reliable operation. Electric vehicles have a simpler powertrain comprising fewer components that work collaboratively to drive the vehicle[7].as shown in figure 1

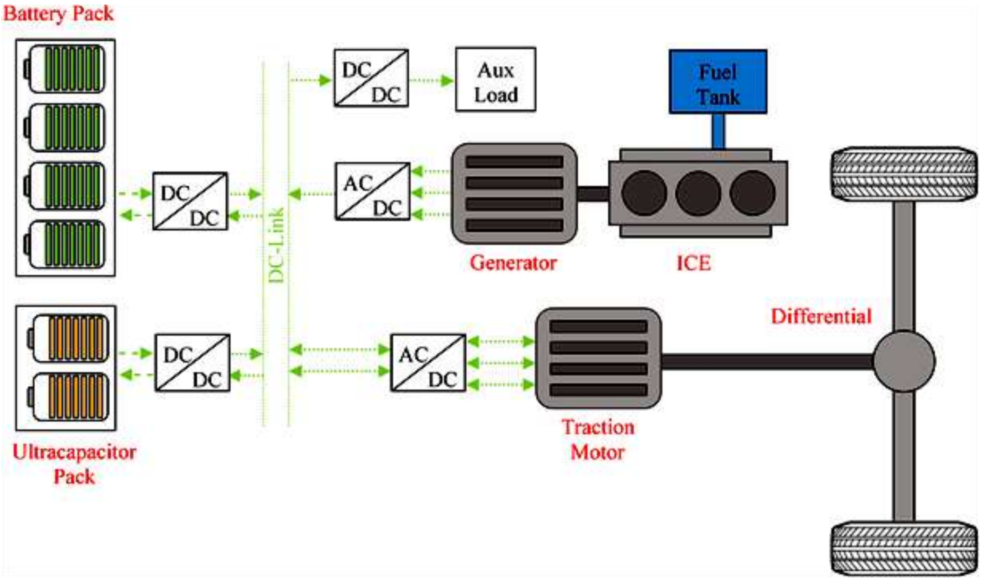

Figure .1 Powertrain

In the Power train one of the essential components is battery. The battery is the cornerstone of any electric vehicle (EV), serving as the primary energy storage system as shown in figure 2. The main function of the battery is to the store chemical energy, which is converted into electrical energy to power the electric motor. As the battery provides the necessary power to accelerate, maintain speed, and overcome resistance, such as hills and wind. It also has the property of regenerative breaking, when the vehicle brakes, the electric motor functions as a generator, converting kinetic energy back into electrical energy, which is then stored back into the battery. The capacity of the battery is measured in kWh (Kilo watt - hour), which determines how much energy the battery can store, directly affecting the vehicle's range. Larger the capacity, longer the range[8]-[9].

Figure .2 EV Battery Pack

Second component Electric motors are the driving force behind EVs. They convert electrical energy into mechanical energy, which rotates the wheels and propels the vehicle. Unlike gasoline engines, electric motors don't burn fuel, making them emissions-free and quieter. Third component power converters are essential components in EVs that facilitate the conversion of electrical energy between different components of the vehicle. As technology continues to evolve, power electronics will play an increasingly vital role in driving the future of electric mobility[10].

3. Results and Discussion

Simulating an electric vehicle (EV) using MATLAB Simulink can be an effective way to analyse and optimize various aspects of the EV's performance. Designing an electric vehicle (EV) model in Simulink involves multiple stages. Simulation and analysis form the second phase of the EV model design process. Simulation parameters are configured, and simulations are run to analyse the vehicle's behaviour under various scenarios. From Table I – V depicts parameters required for proposed work.

Table. I Bridge Parameters

Bridge type	H-Bridge
Output voltage amplitude	320 V
Total bridge on resistance	0.1 Ω
Freewheeling diode on resistance	0.05 Ω
PWM signal amplitude	5.0 V
Enable threshold voltage	2.5 V

Table. II DC Motor Parameters

Field type	Permanent magnet
Armature inductance	12e-6 H
No-load speed	6000 rpm
Rated speed (at rated load)	2538 rpm
Rated load (mechanical power)	29 kW
Rated DC supply voltage	320 V

Table. III. Battery parameters

Type	Lithium ion
Nominal voltage	320V
Rated capacity	15Ah

Table. IV Vehicle Constants

Variable	Value
Mass (M)	1470
Gravitational Force (G)	9.81
Rolling Resistance Coefficient (Rrc)	0.015
Frontal Area (Af)	2.91
Drag Coefficient (Cd)	0.18
Air Density (Rho)	1.2
Gear Ratio (Gr)	9.1
Transmission Efficiency (Te)	0.85
Motor Efficiency (Me)	0.9

Run Time (T)	1400
Wheel Radius (R)	0.332
Voltage (V)	320

Table. V. Vehicle Parameters

Parameters	Urban drive cycle	Sub urban drive cycle	Highway drive
Peak tractive force (N)	1718	1885	1910
Maximum motor torque (Nm)	73.74	80.91	81.98
Rated motor speed (rpm)	4177	6015	7181
Rated motor load (kW)	28.76	40.59	68.49
Battery capacity (kWh)	13.16	18.57	31.34
Distance covered (Km)	7.84	7.99	22.49

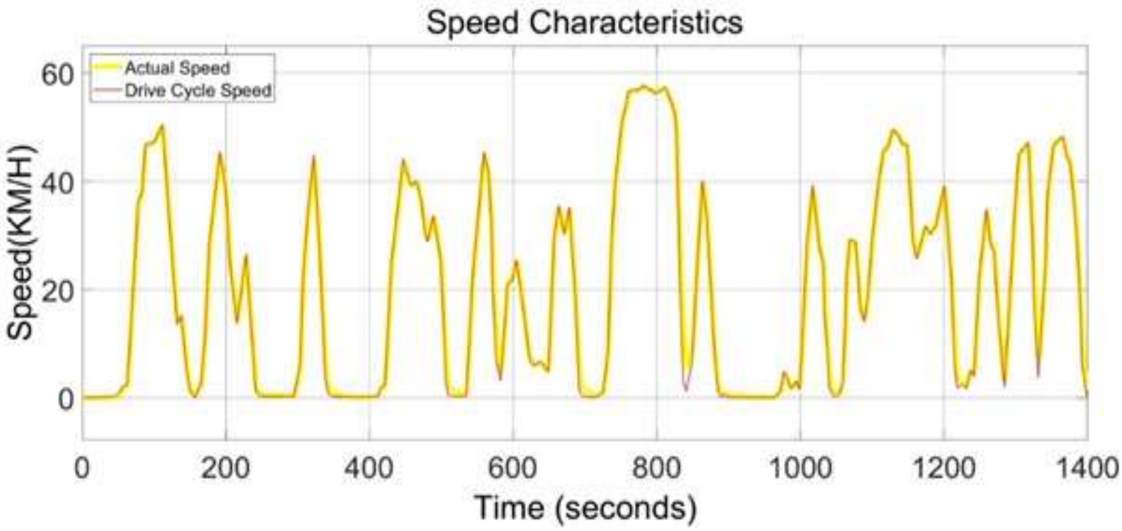

Figure.3 Actual speed Vs Drive cycle speed Urban drive cycle

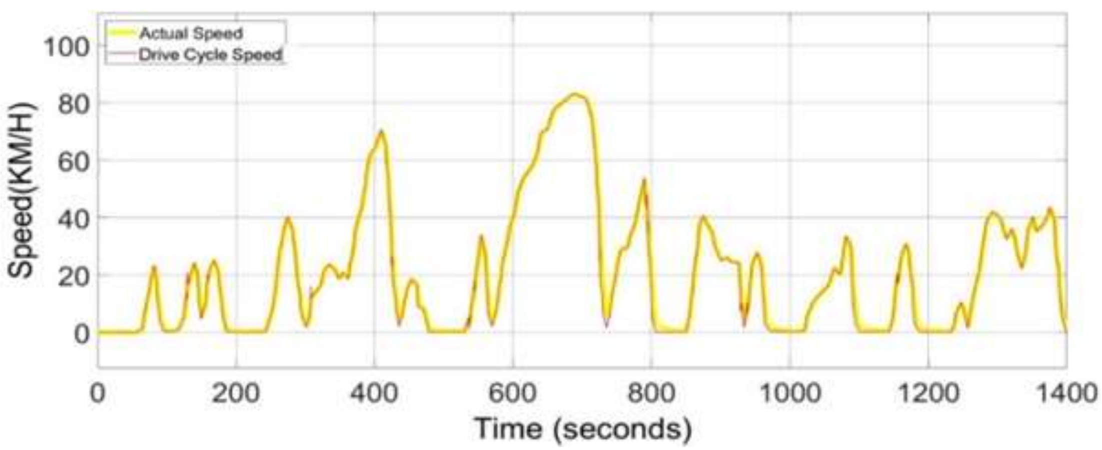

Figure.4 Actual speed Vs Drive cycle speed of Sub urban drive cycle

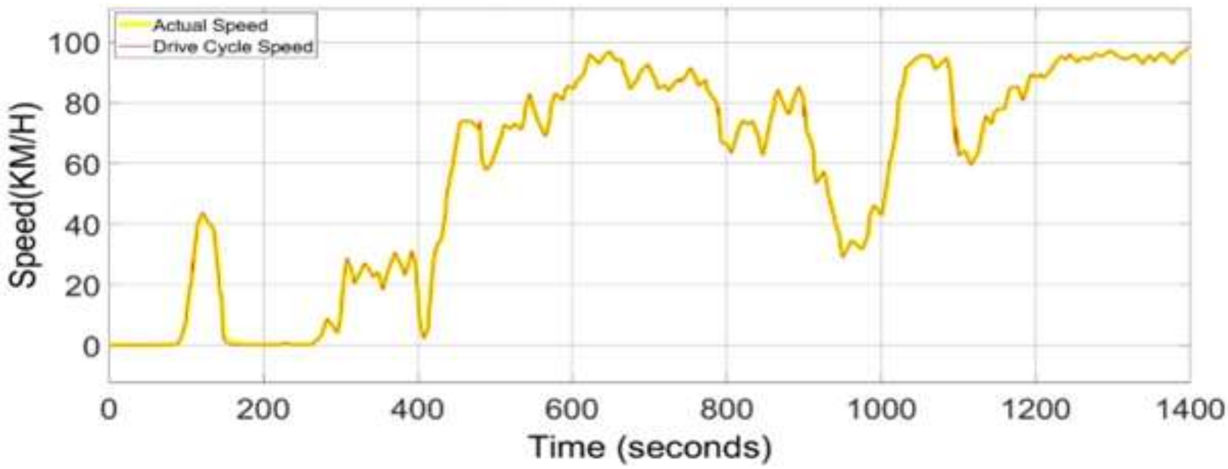

Figure.5 Actual speed Vs Drive cycle speed of Highway drive cycle

From figure 3 the urban drive cycle speed occasionally reaches a maximum of around 57 KM/H, but spends considerable time at lower speeds, and sometimes returns to zero, indicating stop-and-go traffic scenarios. The deviations between the actual and drive cycle speeds are minimal around 0.12%, demonstrating precise speed tracking capabilities. Figure 4 represents the sub urban the actual speed mirrors the target speed with slight deviations. The speed peaks around 85 KM/H, with minor delays and overshoots around 0.55%. Coming to highway drive cycle comparison is in figure 5 the actual speed closely follows the drive cycle speed throughout the period. The fluctuations in the initial and intermediate phases suggest varying traffic conditions, while the high-speed consistency in the final phase indicates a smoother driving environment, reaches peak speed around 100 KM/H.

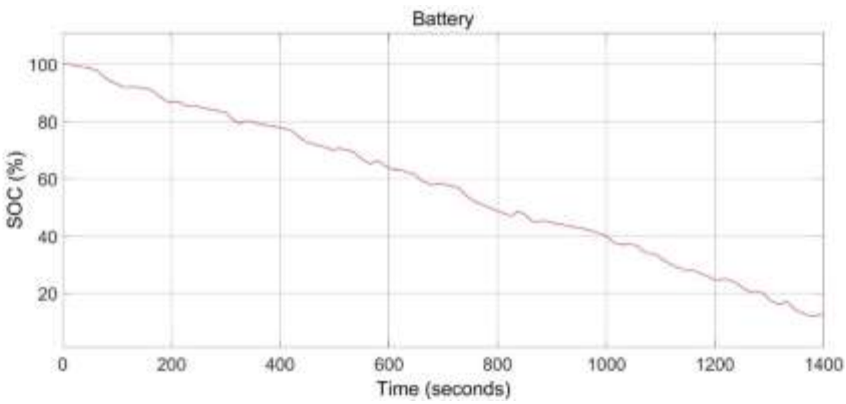

Figure.6 Urban drive cycle SOC

The figure 6 shows the State of Charge (SOC) of the battery over time during an urban drive cycle. The SOC starts at 100% with 13.16 KWh and decreases steadily over the course of 1400 seconds. Upward Slopes indicates regenerative braking, where energy is being fed back into the battery, when compared to other drive cycles urban drive cycle feds more regenerated power to the battery. At the end of the cycle, the SOC drops to just 15%, indicating that approximately 85% of the battery capacity has been used during this urban drive cycle.

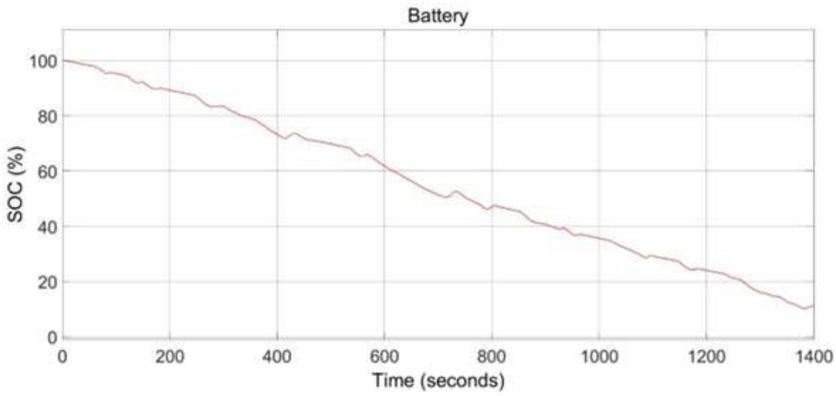

Figure.7 Suburban drive cycle SOC

The figure 7, illustrates the State of Charge (SOC) of a battery over a suburban drive cycle. The SOC decreases at a variable rate, which suggests different energy consumption rates associated with various driving behaviours (acceleration, cruising, and deceleration) typical in a suburban environment. Where the slope either flattens or slightly increases, indicating energy recover due to regenerative braking. Around 90% of battery capacity is consumed

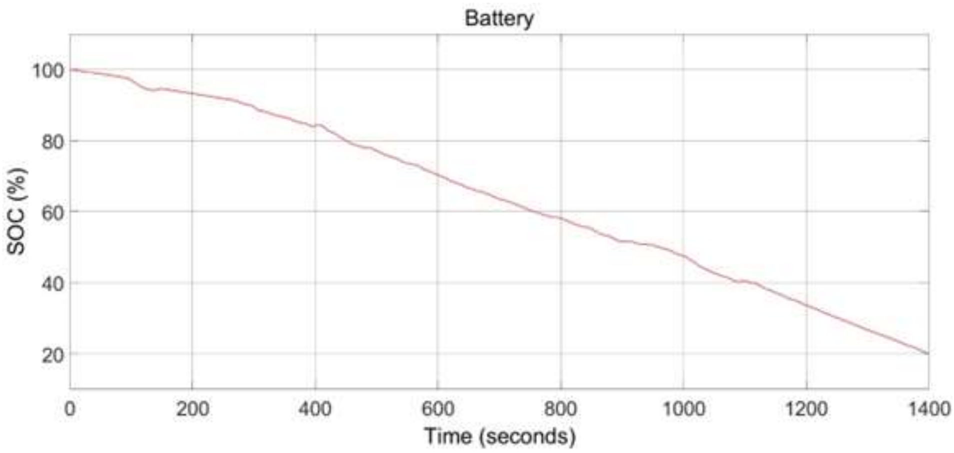

Figure 8 Highway drive cycle SOC

From the above figure 8, the battery discharging characteristics for highway drive cycle is shown. The highway drive cycle resulted in a steady decrease in SOC from 100% to 20% over the course of 1400 seconds, with minimal impact from regenerative braking. This behaviour is typical for highway driving conditions, where continuous driving at relatively high speeds limits the effectiveness of regenerative braking compared to urban or stop-and-go traffic conditions.

4. Conclusion

The sizing estimation of the battery and motor for electric vehicle (EV) applications, based on various drive cycles, provides a crucial understanding of the powertrain's efficiency and performance. By considering multiple factors such as vehicle mass, rolling resistance, frontal area, drag coefficient, air density, and efficiency parameters of both the motor and transmission, accurate sizing ensures optimal energy use and extended driving range. The battery capacity and motor power ratings must be meticulously chosen to meet the energy demands while balancing vehicle weight, space, and cost constraints. Different drive cycles, such as city driving or highway driving, present unique energy consumption patterns, influencing the required battery size and motor specifications. Additionally, by analysing the effects of gear ratio, motor efficiency, and transmission efficiency, the system can be designed for maximum performance with minimal energy losses. The sizing process also requires taking into account the runtime and voltage, ensuring that the battery delivers sufficient power for the vehicle's intended range without compromising on performance or lifespan.

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