

PROTOTYPE BENCH SETUP OF MULTISPEED GEARBOX DRIVETRAIN FOR ELECTRIC VEHICLE

Submitted in partial fulfilment of the requirements for the award of

Bachelor of Engineering degree in Mechatronics

By

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(DEEMED TO BE UNIVERSITY)

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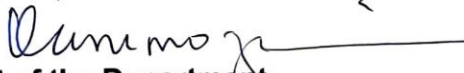
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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of KHARAN V (Reg. No. 40090016) and SAMBUVARAYAN D S(Reg. No. 40090026) who carried out the project entitled **"PROTOTYPE BENCH SETUP OF MULTISPEED GEARBOX DRIVETRAIN FOR ELECTRIC VEHICLE"** under our supervision from November 2023 to April 2024.


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We KHARAN V (40090016) and SAMBUVARAYAN D S (40090024) hereby declare that the Project Report entitled “**Prototype bench setup of Multispeed gearbox drivetrain for Electric Vehicle**” done by us under the guidance of **Dr. M. SANGEETHA, M.E., Ph.D.**, is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechatronics.



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ABSTRACT

An electric vehicle (EV) refers to a mode of transportation utilizing one or more electric motors for propulsion. It can draw power from an external source via a collector system or operate independently through a battery. EVs encompass various forms of transport, including road and rail vehicles, as well as electric boats and underwater vessels (such as submersibles, including nuclear submarines), electric aircraft, and electric spacecraft. Electric road vehicles encompass a wide range, from passenger cars and buses to trucks, and personal conveyances like electric buggies, tricycles, bicycles, and motorcycles/scooters. Alongside emerging automotive technologies like autonomous driving, connected vehicles, and shared mobility, EVs contribute to a future transportation paradigm known as Connected, Autonomous, Shared, and Electric (CASE) mobility. In efforts to mitigate carbon emissions, all car manufacturers are mandated to develop at least one hybrid electric vehicle model. France and Japan have announced plans to cease production of petrol vehicles entirely by 2030. In our project we have incorporated manual transmission with ev vehicles as a bench model since it's a prototype model. This is helpful for efficient usage of torque from the dc motor and also increasing the range of the electric vehicle

The multi-speed gearbox contributes significantly to performance enhancement, enabling better acceleration and achieving higher top speeds, thereby increasing the competitiveness of EVs in comparison to traditional internal combustion engine vehicles. The integration also facilitates the use of smaller and lighter electric motors without compromising performance, resulting in weight reduction and enhanced energy efficiency. Additionally, considerations for adaptive shifting algorithms, market adoption, and regenerative braking optimization underscore the potential future developments associated with the integration of multi-speed gearboxes in EVs, highlighting the ongoing evolution of electric mobility technologies

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LIST OF SYMBOLS AND ABBREVIATIONS

EV	Electric Vehicle
IDC	Indian Drive Cycle
SOC	State Of Charge
DOD	Depth Of Discharge
OCV	Open Circuit Voltage

CHAPTER 1

INTRODUCTION

In Electric Electric vehicle (EV) technologies advanced gradually between the 1830s and 1930s, primarily in traction motor, battery management, and infrastructure to charge batteries, among other areas of development. Following the energy crisis of the 1970s, the importance of EVs was rediscovered due to their significant advantages over conventional internal combustion engine (ICE) cars. An EV produces wheel torque by means of an electric machine or motor that has the potential for more than 85% efficiency, whereas an ICE only has the ability to transform 12-20% of total fuel into usable wheel torque and has a highest efficiency of 40%. Although improving motor technology for electric power has been a primary focus of EV research, the implementation of a multi-speed transmission system in order to improve motor efficiency in EV is a comparatively new idea.

Establishing an efficient transmission system and incorporating it with the current EV propulsion system might have the potential further enhance drivetrain efficiency and the vehicle performance. Manufacturers are using a single-speed gearbox system because it is simpler to minimize cost, weight, waste of energy, or engine mass. With a single-speed transmission system, although EV powertrain efficiency is heavily dependent on the performance of the traction motor or electric motor, which is not similarly effective across all speed phases. For instance, at maximum speed, the motor's torque decreases drastically. Even at maximum speed, the highest torque of the engine decreases substantially despite maintaining a greater efficiency. Vehicles are usually built to meet a variety of driving situations, such as urban driving, interstate driving, and rugged driving.

The traction motor is in charge of delivering a greater range of speed as well as torque in order to satisfy variances in vehicle demand, which causes the traction machine to operate outside of its efficient working zone. The multi-speed transmission concept has the potential to offer a feasible solution for keeping the electric motor effective throughout EV operation. The multi-gear system in an EV aids in the selection of readily obtainable lower-capacity traction motors and batteries by making certain these components are used effectively. Initially,

researchers were concentrating on coming up with enhanced electric motor and battery technology.

According to study findings on EV propulsion systems, each variant of a traction motor has benefits and drawbacks in terms of vehicle performance and motor efficiency. Recent research on EVs with multi-speed gearboxes has demonstrated that upholding efficient motor operation can result in greater performance and powertrain efficiency. The majority of these research focuses on various aspects of a multi-gear concept, such as EV performance in various driving circumstances, gear ratio optimized performance and shift scheduling algorithms, transmission loss computation, and so on. To the best of the authors' knowledge, no review paper has explored the possibility of employing multi-speed transmission systems on EV platforms in a larger context.

1.1 TYPES OF TRANSMISSIONS USED IN IC ENGINES

Here are some common types of transmissions used in IC engines:

Manual transmissions, also known as stick shifts or manual gearboxes, require the driver to manually select and engage gears using a gear lever and a clutch pedal. They offer full control over gear selection, which can be advantageous for performance and fuel efficiency. Automatic transmissions use a hydraulic torque converter to automatically shift gears without direct driver input. They are user-friendly and are often preferred for their convenience, especially in heavy traffic.

Semi-Automatic Transmission, also known as automated manual transmissions (AMTs) or semi-manual transmissions, these systems combine aspects of both manual and automatic transmissions. The driver can manually shift gears without a clutch pedal, or they can allow the transmission to operate automatically.

Continuously Variable Transmission (CVT), CVTs use a belt or chain and pulley system to provide a continuous range of gear ratios instead of fixed gears. They can improve fuel efficiency by continuously adjusting the gear ratio to match engine load and speed. Dual-Clutch Transmission (DCT), DCTs use two separate clutches to pre-select and engage gears, allowing for rapid gear changes and smooth acceleration. They are often used in high-performance and sports cars.

Sequential Manual Transmission, Sequential manual transmissions are commonly found in racing vehicles. The driver shifts gears sequentially, typically using a paddle shifter, without the need for a clutch pedal.

Hydrostatic Transmission. Hydrostatic transmissions use hydraulic fluid to transmit power from the engine to the wheels. They are commonly found in lawn tractors, construction equipment, and some small utility vehicles. Infinitely Variable Transmission (IVT),

IVTs, like the CVT, offer an infinite number of gear ratios, but they operate using different principles, such as hydrostatic drives or mechanical linkages. Manual Transmission (AMT), AMTs are similar to manual transmissions, but they are equipped with an automated clutch system for gear engagement, making them more user-friendly than traditional manual transmissions.

1.2 NOMENCLATURE OF GEARS

The choice of transmission type depends on factors like the intended use of the vehicle, fuel efficiency, performance, and driver preferences.

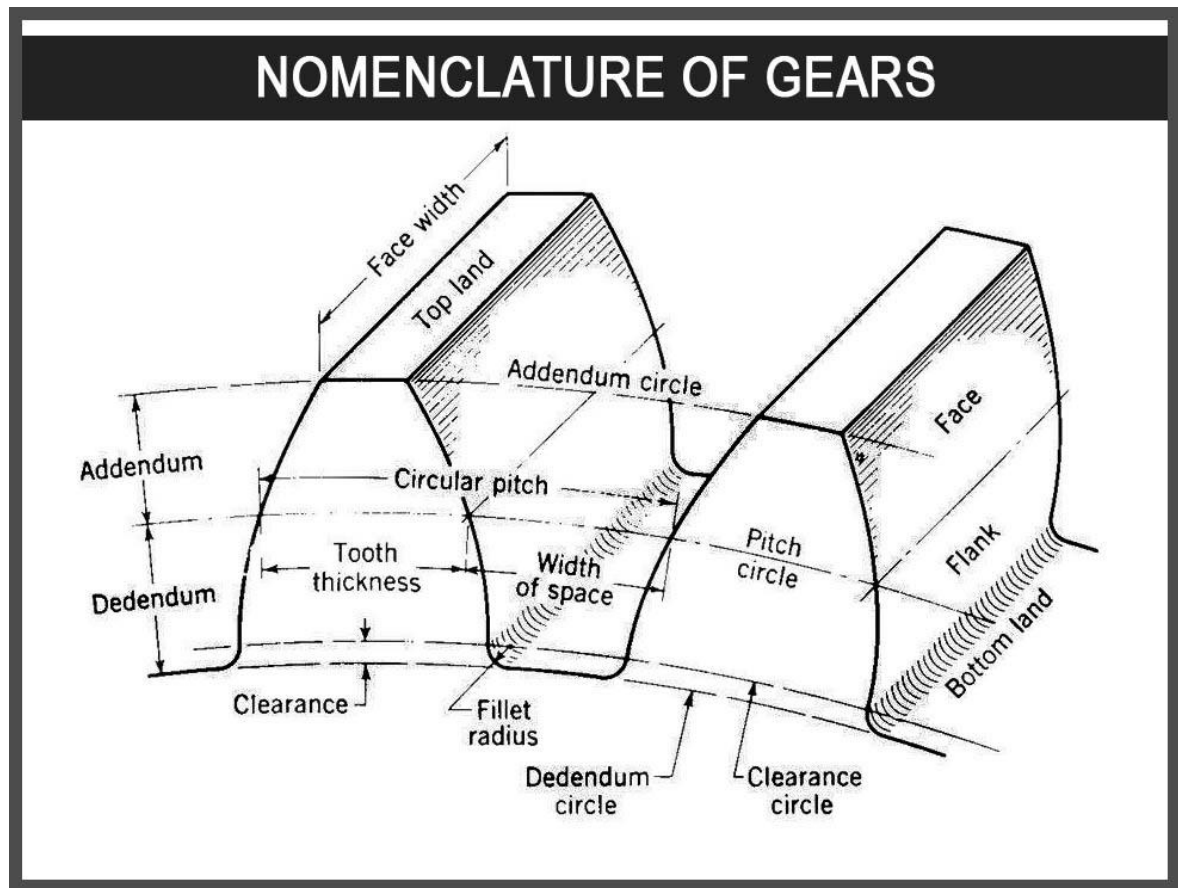


Fig:1.1: Nomenclature Of Gears

With that said, the fundamental gear terminologies are as follows. :In Fig:1.1, the gear exhibits four primary circles: the Addendum circle, which touches the outermost points of the gear teeth; the Pitch circle, an imaginary circle concentric to the gear wheel used for measuring tooth pitch; the Base or root circle, defining the outer limit of tooth spaces in a gear section; and the Dedendum circle, touching the bottom of tooth spaces. Addendum refers to the height by which a gear tooth extends beyond the standard pitch circle, while Dedendum denotes the radial distance inward from the pitch circle to which the tooth profile extends. The Pitch Point is where two pitch circles intersect, lying on the line of centers, while the Line of Action is a tangent line to the base of mating gear circles passing through the pitch point, defining the path of tooth contact. The Pressure Angle is

the angle formed between the line of action and a tangent line at the pitch point. Tooth Thickness is the width of a gear tooth measured along the pitch circle, while Circular Pitch defines the distance on the pitch circle from one tooth point to the corresponding point on the adjacent tooth. Face Width refers to the axial length of teeth, Tooth Face is the surface between the addendum and pitch circles, and Tooth Flank is the surface between the pitch and base circles. Backlash represents the clearance between mating gear teeth.

CHAPTER 2

LITERATURE SURVEY

Daniel Sun et al [1], (2021) provided “vehicular configuration optimization”, which has become an important topic in determining the future prospects of electric cars and simulating energy usage of electric vehicles. Vehicles in metropolitan areas use real-world driving cycle (RWDC) data. First, for RWDC development, operational data from electric commercial cars were acquired. Vehicle configuration parameters such as vehicle body, battery, tyre, and gearbox were selected for simulation in the Advanced Vehicle Simulator (ADVISOR) software package, and the estimated benefits and costs of optimizing each parameter were approximated to provide a benchmark for selecting the controlled variable during the optimization. The controlled variables for the cost-benefit analysis were vehicle mass, rolling resistance coefficient, and accessory power, using the vehicle life cycle driving miles as the benchmark, decreasing the optimization evaluation's short-term profit constraint. The proposed technique might be useful for creating energy optimization methods for electric commercial vehicles. This work serves as the foundation for further research into the energy consumption modelling and economic benefit analysis of electric cars.

Sven Schumacher et al [13], (2021) "optimized the drive train for four- wheeler" by focusing on lap time. The end result is a comprehensive design, simulation, and optimization strategy that takes topological diversity, integrated multi-domain simulation, and a constant linkage to the critical criteria into account. The AVL suite offers the foundation for an architecture of several sorts of virtual, real-time prototype testing for a holistic approach to the vehicle model. Both

simulations are used to verify the ECU's control in the initial implementation level. This is known as "software in the loop" testing because virtual systems are utilized to evaluate dynamic vehicle control. In this scenario, an ECU model created in "MATLAB-Simulink" replaces the ECU. The torque vectoring for the new race vehicle is being developed at this implementation level. The virtual representations of the motor and the ECU are replaced with real components in the second

implementation step. This allows you to evaluate the application of the components on the test bench before the vehicle is finished and adjust it to the components in the best way possible. This is referred to as "hardware in the loop" testing. The planetary gearbox might also be tested using virtual driving profiles generated by the model coupling. Extensive modelling has yielded useful insights into numerous components of the powertrain.

Feyijimi Adegbohun et al [14], (2021) proposed a methodology aimed at designing and developing an electric vehicle (EV) powertrain through comprehensive modeling, simulation, and validation on an actual vehicle system, accompanied by detailed result analysis. Accurate modeling, simulation, and validation of EV powertrains are crucial for making significant design and control decisions in high-performance vehicle designs. While software-based simulation modeling of EV powertrains is essential in the design and development process, validating these models on real-world vehicle systems is equally vital for enhancing overall vehicle reliability, safety, and performance. This methodology employs MATLAB/Simulink software for designing and simulating an EV powertrain, which is subsequently validated on an actual vehicle subjected to performance testing on a chassis dynamometer. The integration of these modeling techniques and real-world validation offers a methodology for efficiently developing and validating high-performance EV powertrains that is cost-effective, addressing gaps in the literature regarding the implementation of such modeling methodologies within a research framework. Additionally, it includes a mathematical overview of EV motion dynamics and the development of an equation-based EV model using the described mathematical models.

Yunkun Xie et al [12], (2020) created a vehicle simulation model focusing on pure battery electric vehicles with a single pedal control system. This model was established and fine-tuned using experimental data derived from vehicle energy flow and driving range analysis. However, it should be noted that the simulation does not account for the thermal aspect of the battery/vehicle. The study delves into the impacts of various environmental and control conditions on energy consumption and driving range of pure electric cars. Key findings reveal that the relative error of battery power and current remains below 5% throughout a single

driving cycle, with the absolute error of battery voltage staying under 2.5 V. The absolute inaccuracy of driving range for the entire range is approximately 5.75 km. Factors such as average vehicle speed, running time, and braking process frequency distribution are identified as primary influencers of energy consumption and driving range. Particularly, in congested traffic scenarios, energy consumption with/without regenerative brake control systems is measured at 46.07 kWh/100 km and 47.19 kWh/100 km, respectively. However, vehicles equipped with regenerative braking exhibit a 2.43% energy savings in congested traffic situations. The model also allows for the adjustment of the energy recovery threshold for the motor's operational state, catering to driver safety in emergency scenarios and optimizing energy conversion. Moreover, the model and data presented in the article can serve as a foundation for future analyses and optimization endeavors aimed at enhancing energy usage and driving range through alterations in alternative technologies or strategies.

Xinxin Zhao et al [5], (2020) developed a model-based system for a two-stage planetary gearbox using AMESim, aimed at validating a seamless shifting method to improve the efficiency of electric cars during the NEDC cycle. The gearbox incorporates a brushless direct current (BLDC) motor, a turbo-worm reducer, two multi-disc wet brakes, and a Simpson planetary gear set. The direction of rotation of the BLDC shaft determines the gear ratio of the transmission, controlled by a designed electronic actuator for shifting. To achieve smooth shifting, state-space equations incorporating transmission control variables were formulated, and a three-stage technique was proposed. Leveraging linear quadratic regulator control, an optimal control strategy was devised for the brake engagement process, considering factors like jerk and friction work. Simulation results suggest that the suggested optimal control approach could minimize sliding friction work of the brake and enhance the shifting quality of electric vehicles (EVs). Furthermore, the ideal control trajectory of the BLDC motor was determined through bench testing of the electronic shifting actuator.

Joonki Hong et al (2016) [11], "A hybrid modelling methodology combining a physics-equation-based model with empirical data", was created. The hybrid power model combines the vehicle dynamics model, the advanced dynamics

model, and the empirical data model. The EV power profile estimate comprises a regenerative braking model, and the EV remaining range estimation incorporates SoC estimation together with a battery model. Real-time testing validates the hybrid model's accuracy in remaining range estimate with the target EV. An on-board monitoring system monitors the EV's power usage, velocity, road incline, and other parameters every half second and conducts a multivariable linear regression to build an accurate EV power model. The electric vehicle's power consumption is modeled, and the remaining range prediction provides just a 2.52% error, whereas the state-of-the-art model-based EV remaining range estimation yields a 9.33% error for the same future route and speed estimation.

Paul D. Walker et al [6], (2013) developed “a model-based design system of an electric car in MATLAB/Simulink”, identified techniques for reaching required range and performance parameters. This article investigates the use of single-speed and two-speed transmission applications to electric cars using system level vehicle models, design analysis, and optimization. Pure electric vehicles (PEVs) provide a unique challenge in powertrain design by achieving performance standards while increasing driving range. As a result, transmission ratios are developed depending on grade and peak speed requirements, and the influence on the vehicle traction curve is assessed. The cars are then compared using performance experiments for various gearbox ratios utilizing both single speed and two-speed powertrain systems. Finally, for single and two-speed PEVs, multivariable optimization in the form of evolutionary algorithms is used to discover an ideal gear ratio selection. The results show that a two-speed gearbox can outperform a single-speed transmission in terms of performance criteria such as vehicle acceleration and hill climbing. However, transmission ratio selection has little effect on economic performance, i.e. energy consumption. Alternatively, a challenging balance is necessary in a single speed gearbox to guarantee that efficiency, acceleration, and peak speed performance qualities are effectively attained.

2.1 LITERATURE SURVEY SUMMARY

Many scholars are investigating various model-based design techniques. MATLAB and AMESim will be used to find the most efficient and appropriate technique. Most studies used a power train with a single speed reduction and direct drive, but they struggled to achieve improved motor efficiency. A motor with a larger torque and speed range is required for the power train with both direct drive and single speed reduction. The motor's losses grow due to the motor's wide range of operation in both torque and motor speed. According to the literature study, adopting a multispeed gearbox can increase the performance of an electric car. The majority of the simulations were for passenger car applications. For example, a vehicle, a bus, and so forth. The cost increase caused by the multi-speed transmission might be offset by lowering the size of the motor and the capacity of the battery.

2.2 PROBLEM IDENTIFICATION FROM THE LITERATURE SURVEY

Though the single-speed reduction gearbox is a simpler system, it requires a large and strong electric motor to function at a higher speed and torque range. The motor efficiency fluctuates when the speed and torque range of the motor is increased. The motor must operate at a greater efficiency range to consume less energy from the battery. According to the literature review, the motor performed at a greater efficiency range and consumed less energy from the battery when used in passenger vehicle and bus applications exclusively. As a result, it decided to test the performance of electric cars with multiple gear ratio.

CHAPTER 3

AIM AND SCOPE

3.1 AIM

To develop a powertrain for a prototype bench setup of Electric Vehicle with Multi Speed Transmission system.

3.2 OBJECTIVE

To develop a powertrain for Electric vehicle with Multi Speed Transmission. To model a prototype bench setup with Multi Speed Transmission system using simcenter AMESim and simulate the same virtually. To test the same in real time and compare the results with the simulated results.

As of my last knowledge update in September 2021, manual transmission electric vehicles (EVs) were not common, primarily due to the reasons mentioned in the previous response. However, technology and the automotive industry are continually evolving, and while manual transmissions are not currently a prominent feature in the EV market, there may still be potential future developments and niches for manual transmission EVs.

Niche Enthusiast Market: There may be a niche market of enthusiasts who appreciate the engagement and control offered by manual transmissions. Some manufacturers could cater to this market by producing limited runs of manual transmission EVs, much like how certain sports car manufacturers continue to offer manual transmissions. **Adaptation for Specific Application in Manual transmissions** could be adapted for specific applications where fine-tuned control over power delivery is required. This might be seen in certain off-road or specialty vehicles, where low-speed maneuverability and precise control are essential. **Hybrid Systems** Manufacturers might experiment with hybrid systems that combine electric motors with internal combustion engines, allowing for manual transmissions to be used in hybrid vehicles. Such hybrid powertrains could find applications in certain commercial or industrial vehicles. **Retrofitted Conversions** used by some automotive enthusiasts might explore the

possibility of retrofitting existing manual transmission vehicles into electric ones, offering a unique driving experience. However, these conversions are often complex and costly. Education and Training for Manual transmission EVs could serve as valuable training tools for new drivers, helping them learn manual driving skills without the complexities of an internal combustion engine. Experimental Prototypes by Automakers and researchers may continue to develop experimental manual transmission EV prototypes to explore the potential benefits or challenges associated with this configuration. The future of manual transmission EVs largely depends on the market demand, advancements in technology, and the willingness of manufacturers to cater to specific niches or adapt to unique use cases.

CHAPTER 4

METHODOLOGY

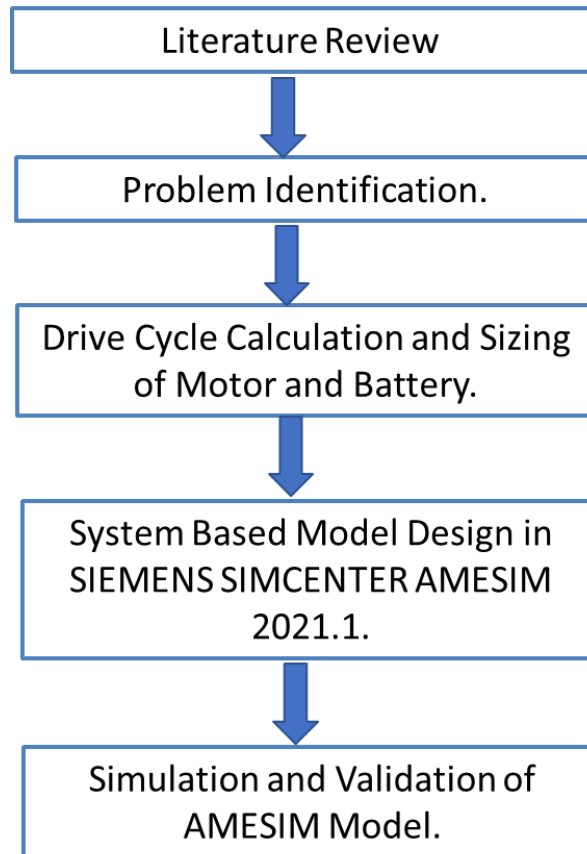


Fig:4.1: Methodology

4.1 EXPERIMENTAL SETUP

Designing an experimental setup(Fig:4.1:) for a multispeed gearbox in an electric vehicle involves orchestrating a comprehensive suite of components and considerations. At its core, the setup revolves around a judicious selection of key elements, beginning with the electric motor. Choose an electric motor with the requisite power and torque specifications tailored for electric vehicle dynamics. Concurrently, identify or design a multispeed gearbox optimized for the electric vehicle application, taking into account crucial parameters like gear ratios and shifting mechanisms. A high-capacity battery system forms an integral part of the setup, providing the necessary power to the electric motor. Complementing these

components, a sophisticated motor controller facilitates precise control over speed, torque, and gear transitions. Instrumentation is paramount, employing sensors for monitoring motor speed, torque, gear positions, and temperature. A well-constructed chassis or test bench, simulating road dynamics through a dynamometer, complements the setup(Fig:4.3:). Safety measures, including emergency shutdown protocols and interlocks, ensure the well-being of personnel and equipment. A Human-Machine Interface (HMI) provides real-time monitoring and control capabilities. The experimental scenarios(Fig:4.2:) cover diverse driving conditions, from acceleration and cruising to deceleration and hill climbing, allowing a comprehensive assessment of the multispeed gearbox performance. Rigorous data analysis, including comparisons with baseline scenarios, forms the basis for evaluating efficiency, power delivery, and overall drivetrain behavior. Throughout this process, meticulous documentation ensures the traceability of methodologies and results for future analysis and optimization. Collaboration with experts in electric vehicle drivetrain design. The 3D render model is given below as (Fig:4.4:)

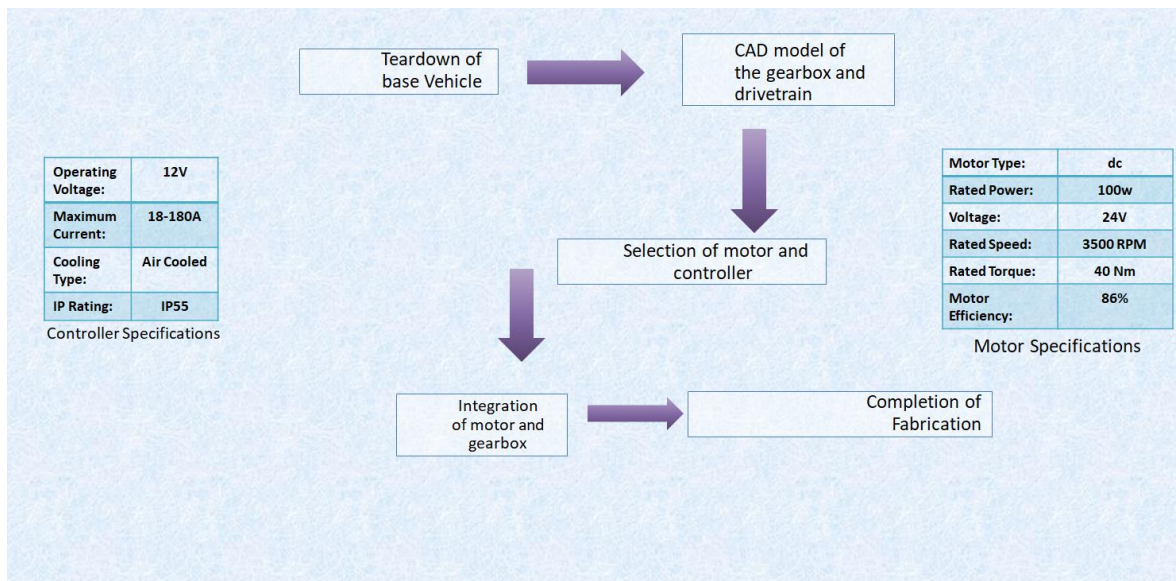


Fig:4.2: Experimental Setup

Operating Voltage	12V	Motor Type	dc
		Rated Power	100w
Maximum Current	18-180A	Voltage	24V
Cooling Type	Air Cooled	Rated Speed	3500RPM
		Rated Torque	40Nm
IP Rating	IP55	Motor Efficiency	80%

Fig:4.3: Specifications of the Controller

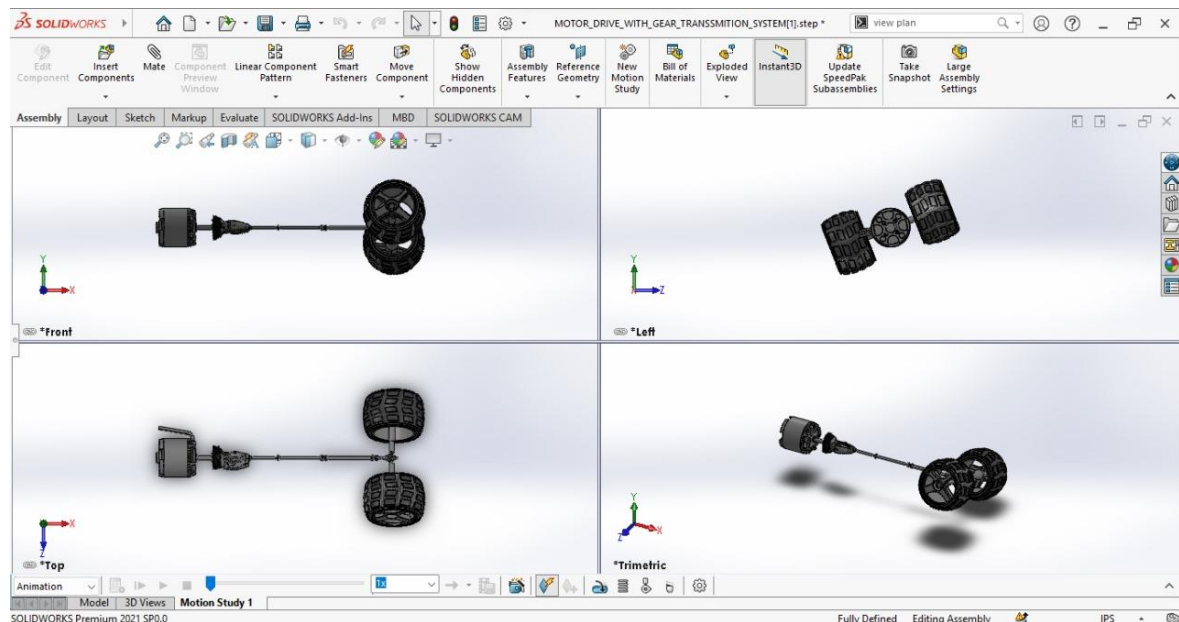


Fig:4.4: 3d Model In Solidworks

4.2 PROBLEM IDENTIFICATION

The difficulty highlighted is that the performance of electric vehicles is not greater than that of internal combustion engine vehicles when employing a single- speed gearbox. Thus, multispeed transmission is sought to improve the performance of EVs.

4.3 DRIVE CYCLE CALCULATION FOR DETERMINING MOTOR SIZE AND BATTERY CAPACITY

Theoretical calculations are performed for determining motor size and battery capacity by creating a drive cycle based on different vehicle parameters taken into consideration such as resistive forces acting on the vehicle, speed, gross vehicle weight, tire size, frontal area etc.

4.4 SYSTEM BASED MODEL DESIGN USING SIEMENS AMESIM

The vehicle System-based model layout for simulating the Light Commercial Electric Vehicle is created and the corresponding vehicle parameters are given as inputs to the model for simulation. This is confirmed in simulation using SIEMENS SIMCENTER AMESIM 2021.1, and the simulation result will be validated with the data recorded from the Prototype that will be made as a proof of concept.

4.5 SIMULATION AND VALIDATION OF AMESIM MODEL

The system-based model is simulated as per the IDC and the results such as Motor Torque Commands, Control Velocities, State of Charge, Range are obtained and will be validated with data obtained from the prototype.

4.6 COMPONENTS USED

4.6.1 Frame

A solid frame to hold the components on the bench setup which has been cut and welded based on our specification

4.6.2 DC Motor

An electric motor is a device that transforms electrical energy into mechanical energy. Its operation relies on the interplay between the motor's magnetic field and the electric current flowing through wire windings, resulting in the production of torque that acts on the motor's shaft. Conversely, an electric generator shares the same mechanical structure as an electric motor but functions in reverse,

converting mechanical energy into electrical energy. Electric motors (see Fig. 4.5) can be powered either by direct current (DC) sources such as batteries or rectifiers, or by alternating current (AC) sources like power grids, inverters, or electrical generators. Various factors, including the type of power source, construction, intended application, and the nature of the output motion, are used to classify electric motors. They can be categorized as brushed or brushless, single-phase, two-phase, or three-phase, axial or radial flux, and may utilize air or liquid cooling systems. Standardized electric motors are extensively utilized in industrial settings, with the largest ones employed in applications such as ship propulsion, pipeline compression, and pumped-storage systems, boasting outputs exceeding 100 megawatts.

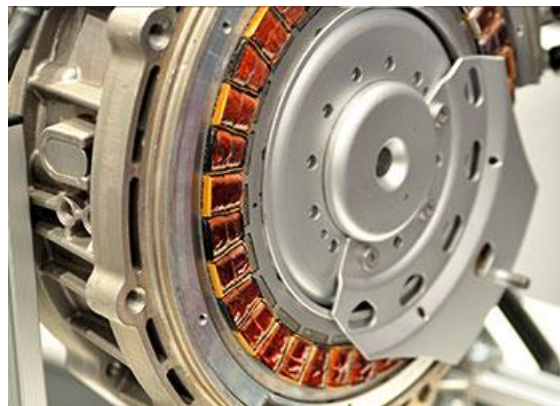


Fig:4.5: Dc Motor

4.6.3 Gearbox

A manual transmission (refer to Fig. 4.6) necessitates the driver's intervention to manipulate both the gear stick and clutch for gear changes, unlike automatic or semi-automatic transmissions, where one or both of these tasks are automated. In most manual transmissions found in cars, drivers have the flexibility to select any gear ratio at any given moment, such as shifting directly from second to fourth gear or from fifth to third gear. However, sequential manual transmissions, commonly utilized in motorcycles and racing cars, only permit gear changes in a sequential manner, either up or down.

In vehicles equipped with a manual transmission, the flywheel is directly connected to the engine's crankshaft and thus rotates at the same speed as the engine. Positioned between the flywheel and the transmission pressure plate is

the clutch disc, which controls the engagement between the transmission and the engine. The transmission's input shaft is linked to the pressure plate, and the clutch pedal governs whether the transmission is connected to the engine (clutch engaged, when the clutch pedal is not pressed) or disconnected from it (clutch disengaged, when the clutch pedal is depressed). When the engine is operational and the clutch is engaged, the flywheel imparts rotation to the clutch pressure plate, thereby driving the transmission.

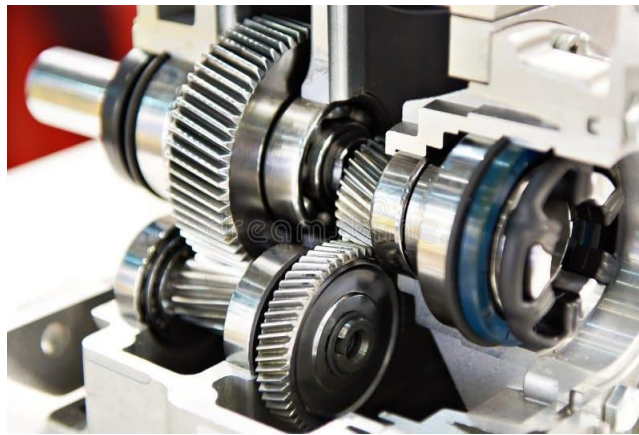


Fig:4.6: Gearbox

4.6.4 Integration of Gearbox and Transmission

5mm thick Mild Steel Plate has been used and the mounting points from the transmission are marked and machined in such a way that the plate holds the motor and transmission together.

4.6.5 Differential

A differential (refer to Fig. 4.7) is a gear mechanism comprising three drive shafts, notable for its ability to ensure that the rotational speed of one shaft equals the average of the speeds of the other two. In motor vehicles, differentials are commonly employed to enable the wheels on each end of a drive axle to rotate at varying speeds, particularly during cornering. Additionally, differentials find application in devices such as clocks and analog computers. Moreover, differentials serve to establish a gear ratio between the input and output shafts,

often referred to as the "axle ratio" or "diff ratio." For instance, in many automotive differentials, a gearing reduction is achieved by incorporating fewer teeth on the pinion compared to the ring gear.



Fig:4.7: Differential

4.6.6 Vehicle Control Unit Module

The Vehicle Control Unit (VCU) functions by receiving input from various sources: the driver, the battery, and the electric motor. Its primary objective is to analyze this data to optimize battery consumption. For instance, the electric motor can serve as a generator during braking, replenishing the battery. The VCU is responsible for transmitting instructions to both the electric motor and the vehicle. Inputs required by the VCU include the maximum and minimum torques of the motor (as depicted in Figure 4.4), motor speed, driver's acceleration and braking commands, gear lever position, and the state of charge of the battery. Conversely, the VCU provides several outputs, including requested motor torque, brake commands, motor speed, maximum and minimum power of the powertrain, and powertrain inertia.

4.7 BENCHMARKING OF PROTOTYPE MODEL OF ELECTRIC VEHICLE

India's urban expansion has resulted in an increase in the number of cities from 5,161 (2001) to 7,935 (2011), as well as an indication of population concentration in cities and existing urban agglomerations. According to 2011 figures, 53 cities had a population of more over a million people, while towns housed around 377 million people². As a result, there has been a significant increase in demand for vehicles for inter-city or intra-city transportation of products and persons.

A significant increase in the number of registered automobiles (25.3 times against 1.77 times population growth between 1981 and 2011) was also seen, underlining the necessity for feasible passenger mobility alternatives.

Millions of cities in India have had a similar pattern of increased automotive population (e.g., Delhi saw an increase from 3,635 vehicles in 2001 to 7,228 in 2011), as well as an increase in difficulties linked to vehicular pollution. Conventional fuel- powered cars, which are currently accessible as forms of transportation, contribute significantly to pollution and emissions, resulting in poor air quality, health concerns, and a variety of other challenges. Cities have recognised the need to address these challenges, and alternate mobility choices are being investigated.

Electric vehicles (EVs) are rapidly being viewed as the most obvious method for mitigating local air pollution via alternatively powered cars. EV technology has recently matured and is being marketed in the context of zero tailpipe emissions. In India, they are quickly becoming a viable alternative to traditional gasoline cars.

The national government plays a crucial role in promoting the transition to electric transportation by implementing various initiatives, plans, and policy support. In India, the government has introduced several measures and incentives to foster the adoption of electric vehicles (EVs). Notably, the FAME program, initiated in 2015 as part of the NEMMP scheme, stands as a prominent example. Under the NEMMP 2020, the government aimed to achieve sales of 6-7 million electric vehicles in India by the year 2020. Substantial government subsidies and the expansion of EV infrastructure across the country, coupled with the entry of

prominent commercial vehicle manufacturers into the electric commercial vehicle market, are anticipated to propel the growth of India's electric commercial vehicle sector in the foreseeable future. Leading participants in this market include Tata Motors, Electra Greentech, Mahindra Electric, Volvo Eicher Commercial Vehicles, and JBM Auto.

Table 4.1: Specifications of Benchmarked vehicles

Benchmark Vehicle	Vehicle -1	Vehicle- 2
Motor Type	3-ph AC Induction Motor	AC Induction Motor
Mode of Transmission	Direct Drive	Single Stage Reduction Gearbox
Battery Type	Li-Ion Battery	LFP Battery
Battery Voltage (V)	72	48
Power Capacity (Ah)	200	229.03
Energy Capacity (kWh)	14.4	21.3
Range (km)	110 km/charge	154 km/Charge
Maximum Speed (Km/hr)	60	80
Motor Power (kW)	11kW @ 3000 RPM	27kW @ 3000 RPM
Maximum Torque (Nm)	90 Nm	130 Nm
Charging Time (Hours)	8-9	6-7

4.8 Benchmark Summary

The vehicles selected for benchmarking are based on various parameters such as GVW (Gross Vehicle Weight), Vehicle Dimensions, Tire Size, Battery Capacity, Range, Type of battery used, Type of motor.

4.8.1 Wheel Torque

Torque is the rotational force which propels the vehicle. Wheel torque is the torque available at the wheel from the power train unit. Generally, the wheel torque is much lesser than the torque supplied by the power unit, as the torque has to be transmitted by various devices and linkages (e.g gearbox, differential), and each torque transfer would cause a loss due to the efficiency of the transmitting system.

$$T = TF \times R_w$$

Where,

T - Wheel Torque (Nm). TF - Tractive Force (N). R_w - Radius of wheel (m)

4.8.2 Wheel Speed

Wheel speed is the speed available or measured at the wheel. The wheel speed can be calculated from velocity using the formula given below:

$$N = V \times 60 / (2 \times \pi \times R_w)$$

Where,

N - Wheel Speed (RPM). V - Velocity (m/s).

R_w - Radius of wheel (m).

4.8.3 Wheel Power

The product of wheel speed and torque is the power available at the wheel

$$P = (2 \times 3.14 \times N \times T) / (60 \times 1000) \dots$$

Where,

P - Power at wheel (kW). N - Wheel Speed (RPM). T - Wheel Torque (Nm).

4.8.4 Motor Speed

The speed of a motor is defined as the rate at which the motor rotates. The speed of an electric motor is measured in revolutions per minute, or rpm.

$$M_s = G.R \times N \dots$$

Where, N - Wheel Speed (RPM).

4.8.5 G.R - Gear Ratio

The reduction ratio is determined using the maximum motor speed and the maximum wheel speed. During each driving cycle, the motor's peak and rated torque are determined. The maximum torque required of the motor is derived by taking acceleration and constant velocity performance at various gradient angles into account.

4.8.6 Motor Torque

The output torque of a motor is the amount of rotational force that the motor develops. The torque of a small electric motor is commonly measured in, Newton-meters (N-m). Using a single-speed reduction ratio, the motor speed, torque, and power are calculated for each vehicle's speed by:

$$M_t = T / (G.R * T_{eff}) \quad [10]$$

Where.

T- Wheel Torque (Nm).

G.R - Gear Ratio.

T_{eff} - Transmission Efficiency.

4.9 DRIVE CYCLE

Drive cycles are patterns of driving in a certain location. It is a graph of velocity vs time. Each geographical area has a unique driving style or pattern. This driving pattern is defined by the topography of the location, the driver's thinking, and the traffic circumstances in that location. It comprises of halting, accelerating, deceleration, idling, and braking phases that are repeated.

Drive cycles are used to evaluate a vehicle's emissions and fuel consumption. A Chassis Dynamometer is used to replicate a driving environment within a laboratory. There are two kinds of driving cycles: modal and transitory. The modal

cycle is made up of periods of straight acceleration and intervals of steady speed.

Modal cycles include the European standard cycle NEDC and the Japanese JC08 mode. Transient cycles feature several speed fluctuations and match to real-world driving scenarios.

The below listed drive cycles which are shown in Table 2 are considered for performing a mathematical calculation to find the power, torque, and speed at wheel and motor on a reference vehicle that has a single-speed ratio. The operating point of the motor such that speed vs torque is calculated for each cycle.

Table 4.2: Time Duration and Speeds of each Drive Cycle

S.No	Drive Cycles	Total Time (s)	Max. Acceleration (m/sec²)	Max. Speed (kmph)
1.	IDC- Indian Drive Cycle	108	0.65	42
2.	NEDC- New European Drive Cycle	799	1.05	50
3.	FTP-75 US EPA	1874	0.57	35
4.	HWFET	765	1.42	77
5.	US06	600	1.45	50

4.10 Indian Driving Cycle

The Indian Driving cycle was the first created indigenously in India to test vehicles for emission and performance. The IDC is a short cycle comprising six driving cycles modes of 108 seconds. The IDC does not cover the complex driving conditions observed on the Indian roads. It consists of a total test time of 648 seconds, a total distance of 3.948 km and a maximum speed of 42 kmph. The

Indian driving cycle comprises of 19 stages that include idling, acceleration and deceleration occurring over a time period of 108 seconds and the vehicle covers a distance of 658m over the course of the Drive Cycle. The speed vs time plot(Fig:4.8:) is obtained from the ARAI website and the datasheet on the 19 stages of IDC is taken to compute/calculate the acceleration and velocity at each second over the course of the entire duration of the Drive Cycle.

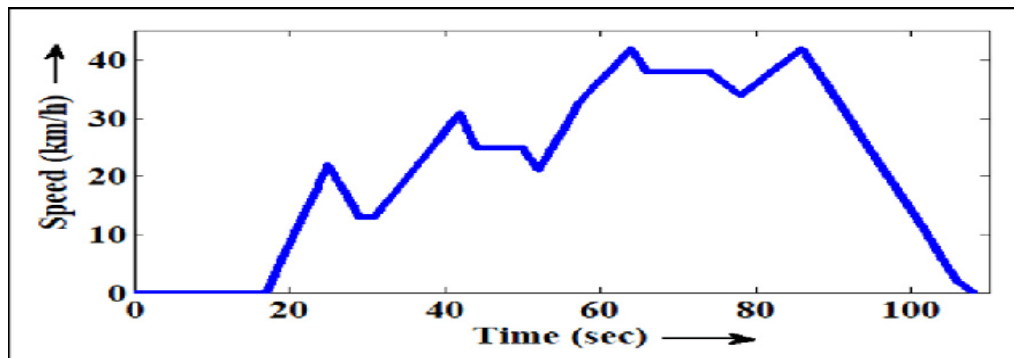


Fig:4.8: Speed vs Time Plot for IDC

CHAPTER 5

RESULT AND DISCUSSION

5.1 RESULTS

Microsoft Excel is used to determine the overall force, wheel torque, wheel power, and wheel speed for each second of the driving cycle. The estimated data is graphed, and the rated power is deduced in (Fig:5.1:) and (Fig:5.2:)

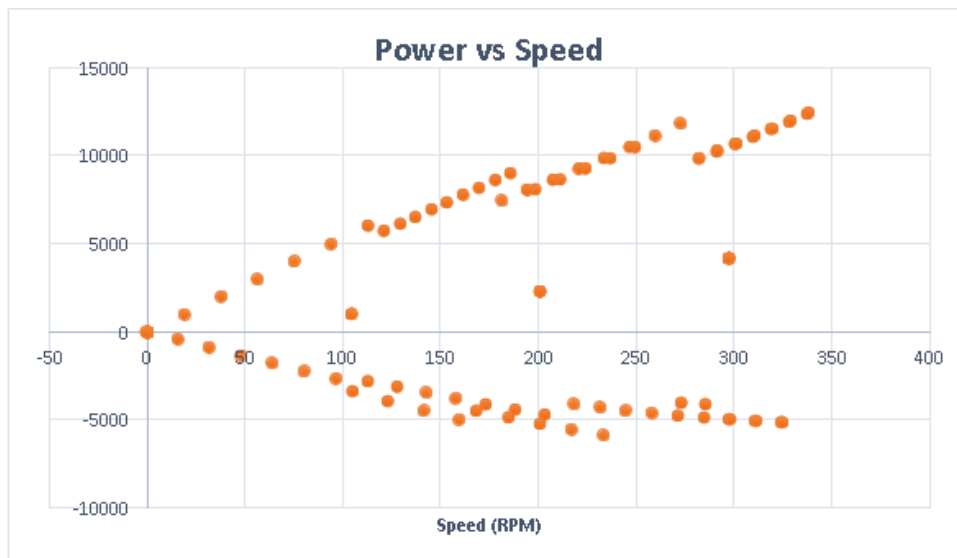


Fig:5.1: Power vs Speed plot

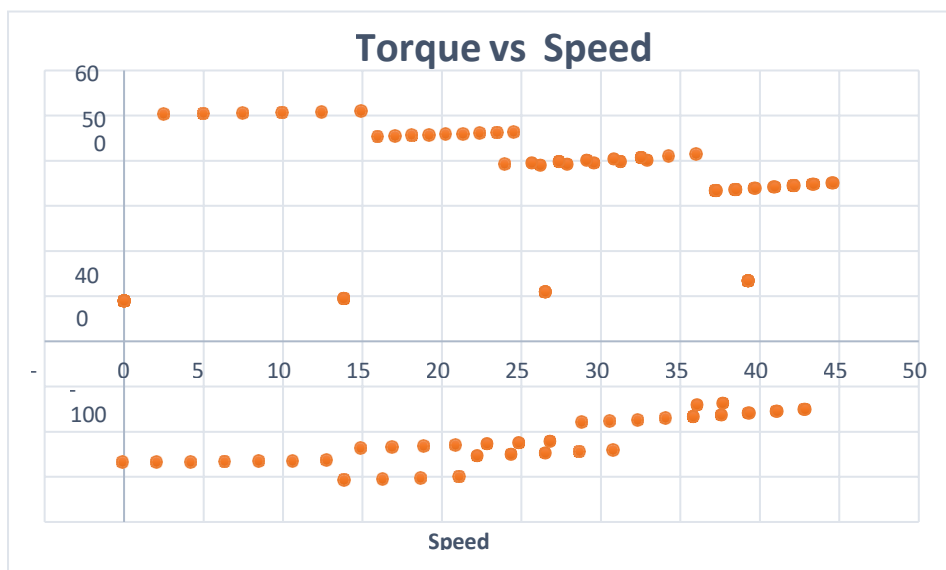


Fig:5.2: Torque vs Speed plot

5.2 MODEL BASED DESIGN AND SIMULATION USING AMESIM

5.2.1 Driver Sub model

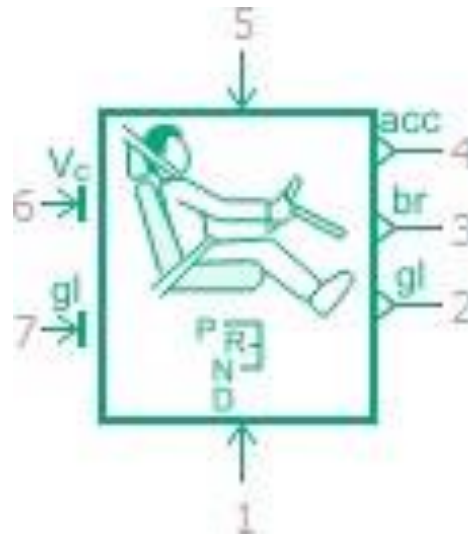


Fig:5.3: Driver Sub model

This sub model(Fig:5.3:) is a longitudinal driver that computes the location of the accelerator, brake, and gear levers in order to follow a velocity target. This goal can be described in several ways,As a function of time,Velocity as a function of displacement,velocity as a function of variable at port 6.In addition to the velocity objective, the gear lever control can be defined in other ways,Only if a specified velocity function of time cycle is used, from file as a function of time, computed by driver, as a function of variable at port 7.The following instructions are computed using model-based control-Acceleration control "acc" [fraction],Braking control "br" [fraction],Gear lever control "gl" [null].

5.2.2 Environment Source



Fig:5.4: Environment Source submodel

This model(Fig:5.4:) is used to build IFP-Drive constant environment.

9 variables sent through port 1 are Environment index, Ambient air pressure, Ambient air temperature, Ambient air density, Windspeed, Road slope, Road/tire grip coefficient, Rolling resistance gain, Altitude.

Variables received in port 2 are Vehicle Speed , Vehicle speed, Vehicle displacement (always increasing even if vehicle is travelling in reverse), Vehicle position.

5.2.3 Vehicle Model



Fig:5.5: Vehicle Submodel

This is a submodel of vehicle(Fig:5.5:). Both front and rear axles are modelled (allowing 4x4 applications) and the user can choose between three vehicle configurations. Road,rolling friction, road slope and aerodynamic drag taken into account.Roller test bench,user defined roller test bench friction coefficients.Coast-down from coast-down file the component computes roller test friction coefficients. Moreover, the user can choose between two longitudinal slip configurations as without slip,no slip between tire and ground. With slip, user defined tire longitudinal slip parameters. Ports 1 and 3 -Braking control, Ports 2 and 4-driving torque [Nm] and return the rotary velocity [rev/min], Port 5 -resistive force when positive or driving force when negative Port 6 and 7-Connected to the environment icon DRVENV01. Port 8, 9 and 10-vehicle speed, vehicle position and altitude. Port 11-Additional load (Kg).Port 12-connected to drivers or information get components.Ports 2 and 4-driving torque [Nm] and return the rotary velocity [rev/min].Port 5 -resistive force when positive or driving force when negative.Port 6 and 7-Connected to the environment icon DRVENV01. Port 8, 9 and 10-vehicle speed, vehicle position and

altitude. Port 11-Additional load (Kg).Port 12-connected to drivers or information get components.

5.2.4 Vehicle Control Unit

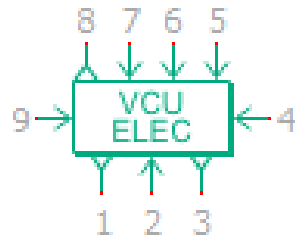


Fig:5.6: VCU submodel

This Vehicle Control Unit receives information from the driver, from the battery and from the electric motor. It analyses them in order to minimize the consumption of the battery. The electric motor could be used as a generator to charge the battery when the driver brakes. The control unit sends commands to the electric motor and to the vehicle. The following inputs are necessary to calculate the outputs.

Inputs are, port 2: motor maximum and minimum torque [Nm],port 4: motor speed [rev/min],port 5: driver acceleration command [0.1, W or Nm],port 6: driver brake command [0.1 or Nm],port 7: gear lever position (1: drive, 0: neutral, -1: reverse) [null],port 9: battery state of charge [%].

Outputs are, port 1: requested motor torque [Nm],port 3: vehicle brake command [0.1], port 8: motor speed, powertrain maximum power, powertrain minimum power and powertrain inertia equivalent mass.The strategy used in this control unit is a basic strategy.

5.2.5 Battery

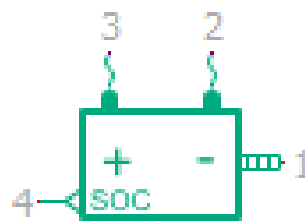


Fig:5.7: Battery submodel

This is a submodel of battery(Fig:5.7:). Voltage can be fixed or variable, State of Charge can be computed or not. In variable voltage case, it includes an internal resistance model. Experimental data are needed to describe the open circuit voltage and the internal resistance. Thermal effects can be taken into account. The open circuit voltage and the internal resistance can depend on temperature. This battery is a concatenation of cells in series and in parallel.

5.2.6 Electric Motor

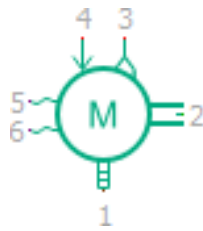


Fig:5.8: Electric Motor submodel

DRVEM03(Fig:5.8:) is a model of electric motor/generator with its converter. The output torque and power losses can be determined either by using data files or characteristic parameters. This model is bidirectional (motor/generator) and independent from the technology of the motor and its converter.

5.2.7 Rotary Speed Sensor



Fig:5.9: Rotary speed sensor submodel

MECRSS0A(Fig:5.9:) is an angular velocity sensor. Normally it is used between a rotary load and a rotary shaft such as a hydraulic motor. The arrow at the icon bottom defines the positive convention of the velocity. All arrows in the sketch (the ones of the sensors and the ones of the rotary loads) have to be oriented towards

the same direction. Therefore, the output signal at port 2 would not depend on the side of the rotary load it's connected to. The direction of the arrow can be changed either in sketch mode by flipping the icon, or in parameter mode with an enumeration. The velocity in rev/min is input at port 3 and is passed without modification to be output at port 1. The torque in Nm is input at port 1 and is passed without modification port 3.

5.2.8 Reducer

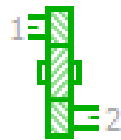


Fig:5.10: Reducer submodel

This is an efficient mechanical gear ratio. It computes the velocity output assuming 100% mechanical efficiency by multiplying the rotational velocity in rev/min input by the gear ratio supplied by the user. This gear ratio is also multiplied with the torque in Nm input to get the output torque.

5.2.9 Multi Speed Transmission

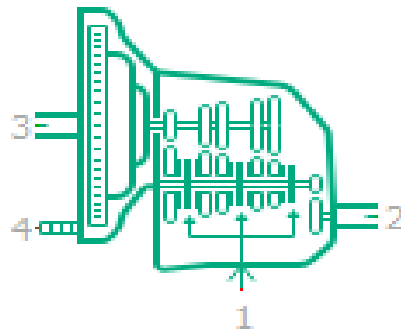


Fig:5.11: Multispeed Gearbox submodel

This model may be used to create a rudimentary dynamic representation of an n-ratio (forward and backward) manual gearbox. The losses in the gearbox(Fig:5.11:) are the same for each gear. The primary shaft inertia and the powered axle are considered. The gearbox gear control is the signal input at port 1; this variable is an output for the "driver" component. The input to port 2 is the rotating velocity of the wheels, and the output is the driving torque given to the wheels. The input to port 3 is engine torque, and the output is engine rotary velocity. The fourth port is a thermal port. The output is the power (in W) generated by the gearbox.

5.2.10 Function Model For 1d Input

This model(Fig:5.12:) reads a 1D table and interpolates the data as a function of 1 input signal. The 2D mesh can also be created with a multiple set of 1D splines. The result is a 2D mesh with less constraints on data points in the x horizontal direction. The 1D splines created in the x direction can be linear or cubic, but the interpolation is also linear as well as cubic.



Fig:5.12: 1D Input Submodel

5.3 ELECTRIC VEHICLE SYSTEM MODEL USING SINGLE SPEED REDUCTION

This research compares the performance of an electric car with a single speed decrease to the performance of an electric vehicle with a multistage reduction. The above-mentioned models are used to build the entire system. The electric vehicle system is first built with a single speed decrease. The necessary input and output connections are created between the models, and the system is finished. The needed submodels are selected based on the current situation.

Amesim is divided into four segments that must be completed in order to complete the simulation. They are as follows: Sketch, Submodel, Parameters, and Simulation. The Sketch and sub model processes are utilised to design the entire system by utilising the necessary sub models. The parameter section is where you enter the parameters needed for simulation. Finally, the simulation component is utilised to model the entire system and obtain results.

The model(Fig:5.13:) replicates an electric vehicle's behavior for several normalized cycles. The model's ultimate goal is to determine if the computed motor and battery specifications fulfil the Indian Drive Cycle. Another use of the approach is that some testing may be done in a virtual environment and the findings compared to real-world testing results. The illustration below depicts an electric automobile. All critical characteristics are evaluated, including the ambient circumstances at the testing site.

Light Commercial Electric vehicle with Single Stage Reduction

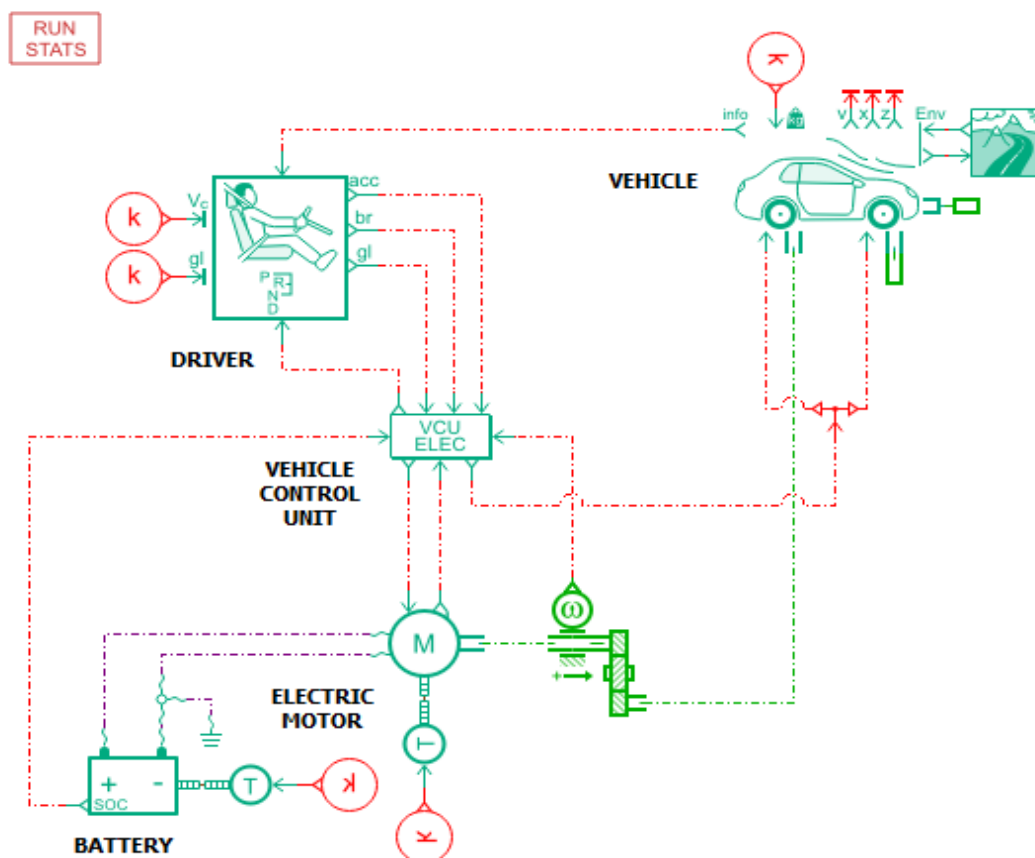


Fig:5.13: Layout of Electric Vehicle with Single Stage Reduction

5.4 ELECTRIC VEHICLE SYSTEM MODEL USING MANUAL TRANSMISSION

This system(Fig:5.14:) consists of a 4 speed Manual Transmission with a control table that provides the gear ratio required based on the required condition of speed and torque. The multiple 1 – Dimensional table is given input and the output is based on the interpolated vales of the table.....

Light Commercial Electric vehicle with Multispeed Transmission

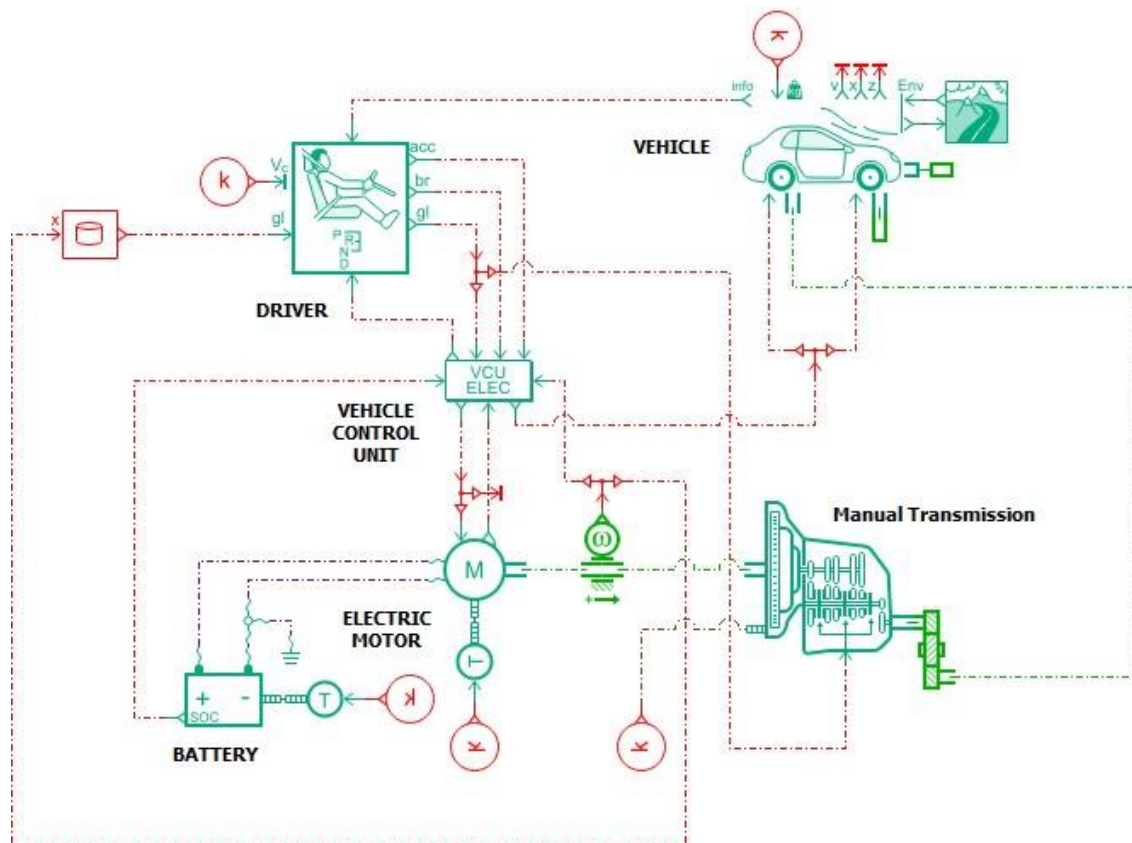


Fig:5.14: Layout of Electric Vehicle with Multi Stage Reduction

5.5 PARAMETERS GIVEN IN SIMULATION FOR ELECTRIC VEHICLE SINGLE STAGE REDUCTION:

Table 5.1: Parameters for Electric Vehicle with Single Stage Reduction

S. No	Constant	Value	Model
1	Coefficient of Drag	0.6	Vehicle
2	Density of air (Kg/m ³)	1.226	Environment
3	Acceleration due to gravity (m/s ²)	9.81	*
4	Gradient (In degrees)	0	*
5	Mass of the Vehicle considered - Gross vehicle weight (Kg)	735	Vehicle
6	Frontal Area (m ²)	2.22	Vehicle
7	Radius of the wheel (m)	0.28	Vehicle
8	Mass factor	1.05	*
9	Final Drive Gear ratio	6.444	Reducer
10	Wheel used for computation	rear	Driver
12	Maximum Braking torque	100 Nm	VCU
13	Torque repartition during regenerative braking	40%	VCU
14	Maximum positive torque	50 Nm	Motor
15	Torques definition	Constant	Motor
16	Negative torque definition	Reversed from positive torque	Motor
17	Losses definition	No losses	Motor
18	Motor torque at port 2	*File*	Motor
19	Voltage for computation	72 V	Battery

5.6 PARAMETERS GIVEN IN SIMULATION FOR ELECTRIC VEHICLE WITH MULTI STAGE REDUCTION:

Table 5.2: Parameters for Electric Vehicle with Multi StageReduction.

S. No	Constant	Value	Model
1	Coefficient of Drag	0.6	Vehicle
2	Density of air (Kg/m ³)	1.226	Environment
3	Acceleration due to gravity (m/s ²)	9.81	*
4	Gradient (In degrees)	0	*
5	Mass of the Vehicle considered – Gross vehicle weight (Kg)	690	Vehicle
6	Frontal Area (m ²)	2.22	Vehicle
7	Radius of the wheel (m)	0.28	Vehicle
8	Mass factor	1.05	*
9	Final Drive Gear ratio	6.444	Gear Ratio
10	Wheel used for computation	rear	Driver
11	Maximum Braking torque	100 Nm	VCU
12	Torque repartition during regenerative braking	40%	VCU
13	Maximum positive torque	50 Nm	Motor
14	Torques definition	Constant	Motor
15	Negative torque definition	Reversed from positive torque	Motor
16	Losses definition	No losses	Motor
17	Motor torque at port 2	*File*	Motor
18	Voltage for computation	72V	Battery
19	Battery Capacity	32Ah	Battery
20	4 Speed Manual Gearbox Ratios	4.231:1, 2.143:1, 1.207:1, 0.954:1	Gearbox

21	Interpolation type	linear	Gearbox
22	Data out of range mode for linear splines	Linear extrapolation	Gearbox
23	Table 1D interpolation type	linear	Function
24	Data out of range mode	Linear extrapolation	Function
25	Name of the ASCII file	*File Name*	Function
26	Output Value	u	Function

5.7 SIMULATION RESULTS

5.7.1 Introduction

A powertrain design for a common Light Commercial Electric Vehicle gearbox is provided, consisting of a manual transmission and a fixed gear transmission. LCVs with cargo capacity of around 710kg typically have a gross vehicle weight of 1.2 to 1.5 Tons. These vehicles never surpass 60 km/h in speed, and their typical operational speed is 30 km/h. The routes chosen have a maximum trip distance of 4 to 15 km and grade degrees ranging from 3 to 11. One of the reasons these vehicles are so little is that they drive on city slopes, which are often narrow and with a short curvature radius. The following parameters were utilized in the vehicle powertrain analysis: gross vehicle mass of 1495 kg, aerodynamic drag coefficient of 0.6, front area 2.24 m², air density 1.226 kg/m³, rolling coefficient of 0.015, and wheel diameter of roughly 0.28 m. The goal of the project is to increase the range of the Light Commercial Electric Vehicle by adopting a Multi Speed Transmission System.

5.7.2 Motor Torque for IDC

Figures(Fig:5.15:) and (Fig:5.16:) compare the torque needed at the wheel (Nm) produced from mathematical modelling at various instants of time (sec) for a single stage reduction and a Multispeed Transmission, respectively. Because the two back wheels are symmetrical, a single motor arrangement will be equally distributed to each individual wheel. A fixed gear ratio is employed in this case to reduce the load torque requirement at the motor shaft.

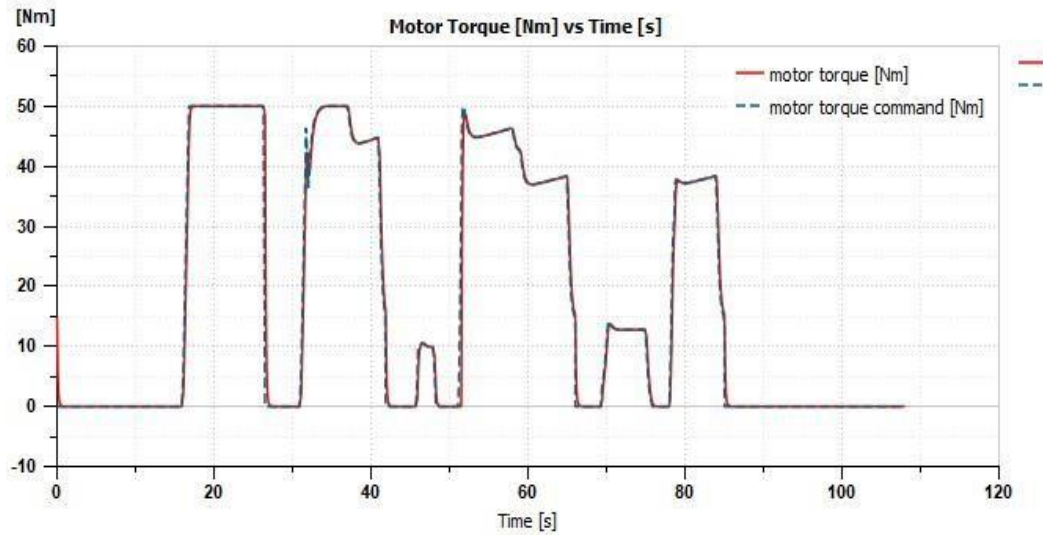


Fig:5.15: Motor Torque vs Time. (Single Stage Reduction)

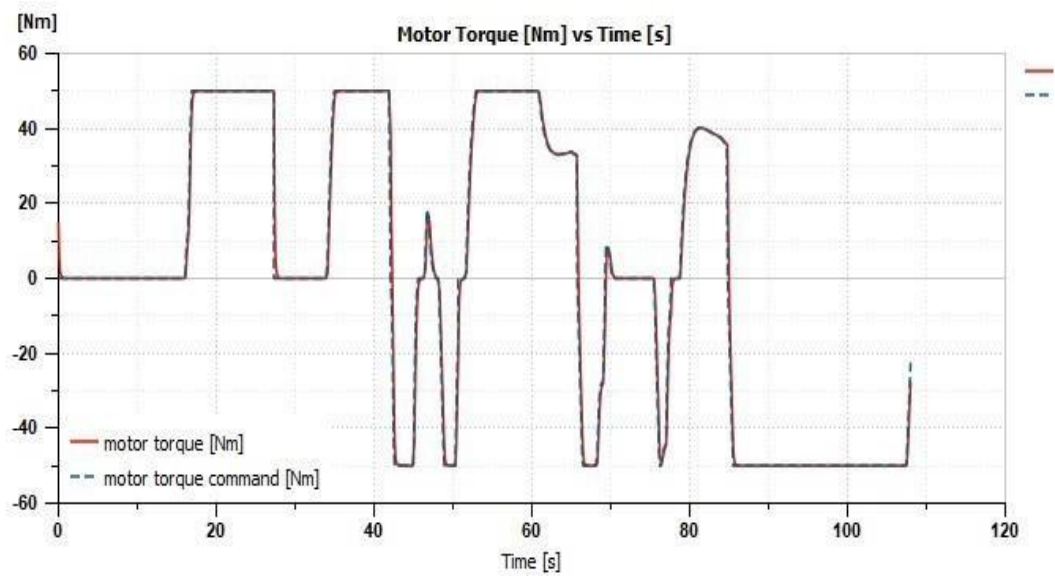


Fig:5.16: Motor Torque vs Time. (Multi Stage Reduction)

5.8 RANGE

The vehicle's range is computed by calculating the change in SOC per cycle for the distance travelled during the cycle. As a result, the total available charge in the battery, as well as the change in SOC each cycle and distance travelled per cycle, will determine the vehicle's range.

$$\text{Range} = 80 * \text{distance} / \text{delta_soc}...$$

As a result, the overall range of the car with a single stage reduction is 112.80 km, as shown in Figure(Fig:5.15:) and the range of the vehicle with a CVT is 122.36 km, as shown in Figure(Fig:5.16:)

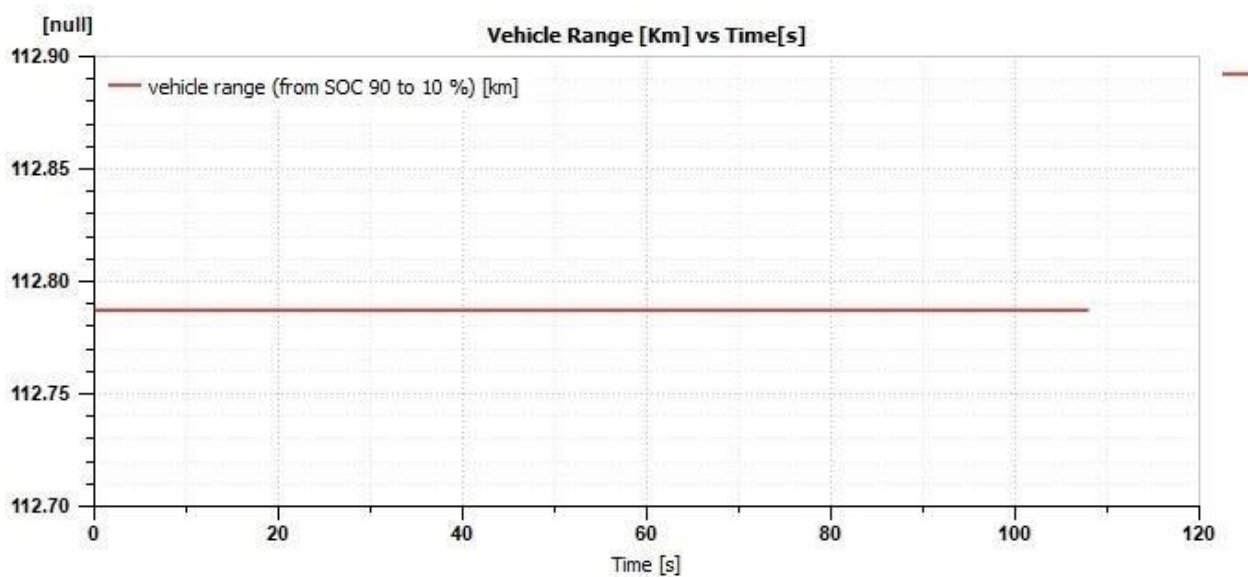


Fig:5.15: Range vs Time. (Single Stage Reduction)

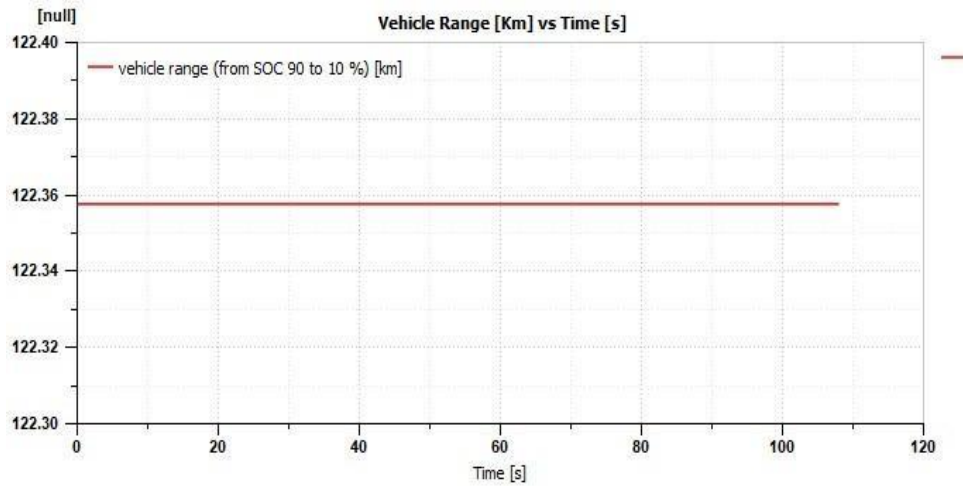


Fig:5.16: Range vs Time. (Multi Stage Reduction)

5.9 MOTOR EFFICIENCY CURVE

Figure(Fig:5.17:) shows the motor loss plot at various voltage inputs, which impacts the efficiency of motor operation. The findings show that the motor performs at optimum efficiency in the blue zone with lowest losses. Maximum efficiency may be gained by operating the motor at appropriate torque and speed ranges of 40-50 Nm and 3500-4500 RPM.

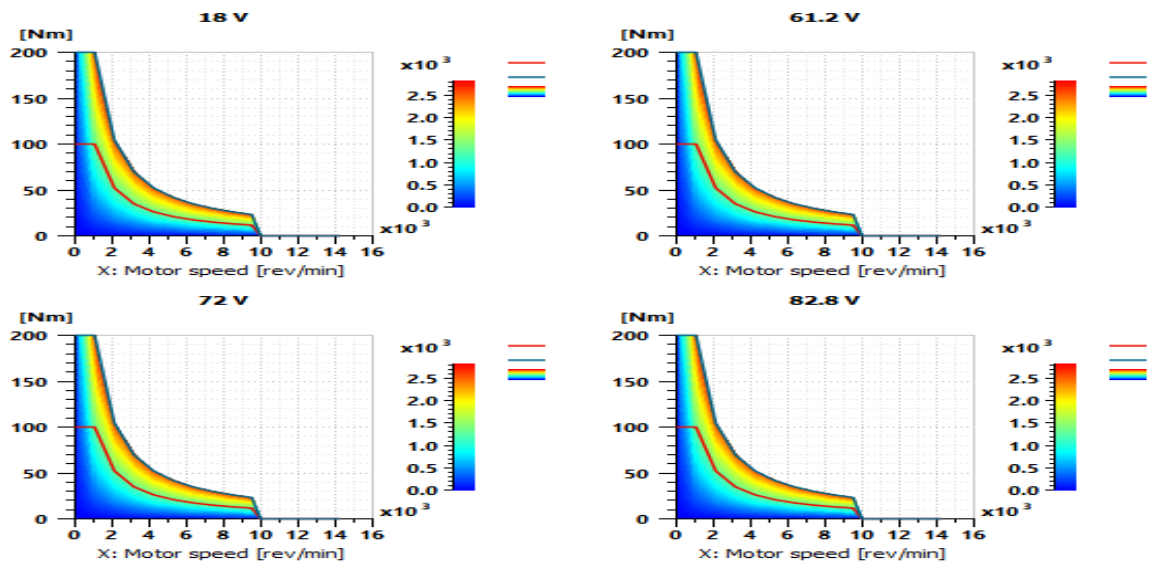


Fig:5.17: Motor Efficiency Curve at different voltages

5.10 GEAR SHIFT POINTS

The graph below (Fig:5.18:) depicts the gear shift points of a 4 Speed Manual transmission System depending on RPM for Indian Drive Cycles lasting up to 108 seconds with gear ratios of 4.231:1, 2.143:1, 1.207:1, and 0.954:1 respectively

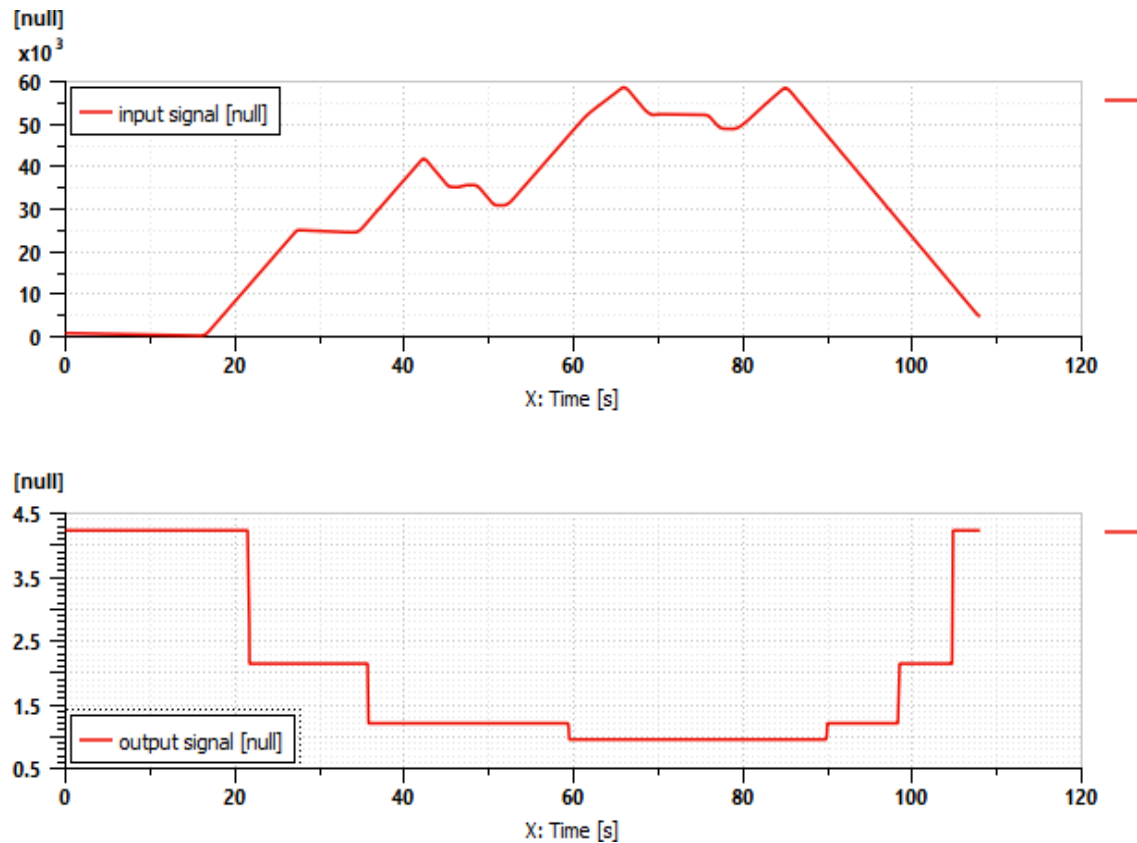


Fig:5.18: Gear shift Plot vs RPM

5.11 MOTOR CONTROL VELOCITY Vs VEHICLE VELOCITY

Motor velocity command is obtained from the VCU to be given to the motor as an input. The vehicle velocity must match the control velocity in order to achieve the drive cycle pattern. The results show that for both the electric vehicle – with single speed reduction and with multi speed transmission the control velocity closely matches with the vehicle velocity. Its shown below in graphs(Fig:5.19:) and(Fig:5.20:)

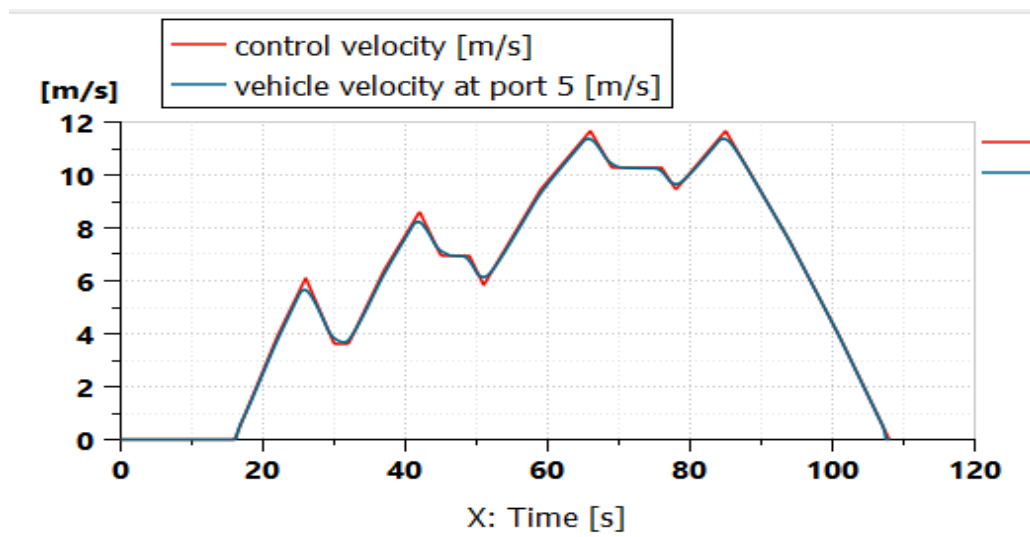


Fig:5.19: Control Velocity vs Vehicle Velocity. (Single Stage Reduction)

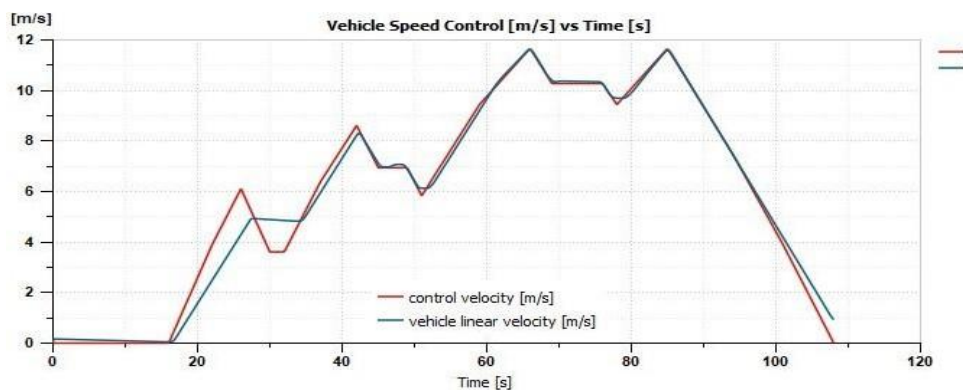


Fig:5.20: Control Velocity vs Linear Velocity. (Multi Stage Reduction)

CHAPTER 6

SUMMARY AND CONCLUSION

In conclusion, the design and fabrication of a multispeed gearbox drivetrain for an electric vehicle (EV) is a multifaceted and critical undertaking. This project offers the potential to significantly enhance the efficiency, performance, and range of EVs, ultimately contributing to the advancement of sustainable transportation. The following key takeaways can be drawn from this process.

Efficiency and Performance Improvement, Multispeed gearboxes provide the means to optimize power delivery, enhancing both acceleration and cruising efficiency. This directly impacts the overall performance of the EV, making it a more attractive choice for consumers.

Customization and Optimization, the design process allows for customization and optimization of gear ratios to suit the specific requirements and driving conditions of the EV. This flexibility is crucial for achieving the best balance between power and energy consumption.

Material Selection and Manufacturing Precision, Choosing the right materials and manufacturing processes are essential for creating lightweight yet robust gearbox components.

Safety and Reliability, Safety mechanisms and redundancy systems are integral to protect both the gearbox and the overall vehicle. Implementing these features can help prevent damage and ensure the safety of passengers and other road users.

Testing and Quality Assurance Rigorous testing and prototyping are fundamental to the development process. Thorough evaluation under various conditions helps identify and rectify potential issues, ensuring the gearbox's reliability and durability.

Maintenance and Serviceability, Designing for ease of maintenance and serviceability is essential for reducing the long-term operational costs of the EV. It also ensures that repairs and replacements can be performed efficiently.

Regulatory Compliance and Documentation, adhering to safety and emissions regulations is crucial to ensure the legality and marketability of the EV. Proper documentation and manuals facilitate maintenance and compliance.

Collaboration and Expertise, multispeed gearbox design and fabrication require a multidisciplinary team of engineers, mechanics, and electricians. Collaboration and

consultation with experts in EV drivetrains can help overcome challenges and address specific technical nuances. Sustainability and Market Impact, the project ultimately contributes to the advancement of sustainable transportation, reducing carbon emissions and reliance on fossil fuels. Furthermore, if the gearbox is marketable, it can influence the broader EV industry by improving efficiency and performance. In summary, the design and fabrication of a multispeed gearbox drivetrain for electric vehicles is a complex and valuable endeavor. By combining advanced engineering principles, precision manufacturing, and rigorous testing, this project has the potential to shape the future of electric mobility, making it more accessible, efficient, and environmentally friendly.

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