ELECTRIC VEHICLE WITH MANUAL GEAR SYSTEM

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Abstract

The performance of electric vehicles (EVs) can be significantly enhanced by using multi-speed transmissions instead of single-speed transmissions. Multi-speed transmissions offer advantages such as higher top speeds, faster acceleration, better ability to climb steep gradients, and increased driving range. This study extensively examines relevant literature to investigate the performance characteristics and complexities associated with multi-speed automatic manual/mechanical transmission (AMT) systems in EVs.

In an EV powertrain, the electric motor is the sole torque generator component. However, the motor's efficiency varies across a wide range of speeds, while vehicles need to operate at different speeds under various driving conditions. The study reveals that a multi-speed transmission system allows for efficient operation of the electric motor by selecting the appropriate gear based on the required torque and speed, thereby achieving desired vehicle performance with minimal energy consumption. To illustrate the differences, the study compares the dynamic and economic performance of EVs equipped with multi-gear systems versus single-speed systems. The findings are presented through tables and bar charts.

Index Terms—*Manual Gear System*

I. INTRODUCTION

Between the 1830s and 1930s, there was a gradual development of electric vehicle (EV) technologies, particularly in areas such as traction motors, battery capacity, and charging infrastructure. However, it was after the oil crisis in the 1970s that the importance of EVs was once again recognized due to their significant advantages over conventional internal combustion engine (ICE) vehicles. EVs achieve more than 85

Developing an efficient transmission system and integrating it with the existing EV powertrain can contribute to improved drivetrain efficiency and vehicle performance. An EV can be directly driven by the motor, or a transmission system can be implemented between the motor and the wheels to optimize vehicle performance. Vehicles are designed to accommodate various driving conditions, such as city driving, highway driving, and hilly terrains. The traction motor needs to supply a wider range of speed and torque to meet the variable demands of the vehicle, which may require the motor to operate outside its efficient region. The idea of a multi-speed transmission offers a practical solution to maintain motor efficiency during EV operation. However, this system introduces additional complexities, which will be discussed in detail. Implementing a multi-gear system in EVs helps optimize the utilization of traction motors and batteries, allowing for the selection of smaller and lower-capacity components. Initially, researchers focused on improving electric motor and battery technologies, but soon recognized the crucial role of the transmission as a powertrain component to enhance EV performance.

This study aims to explore different types of multi-speed transmissions in EVs and review recent works on incorporating multi-gear automatic manual/mechanical transmissions (AMTs) in passenger electric cars (E-cars) and public electric buses (E-buses). The performance of multi-gear systems will be compared to direct-drive systems within the EV platform, considering factors such as range, comfort, and driving conditions. Although literature suggests that adding more than one gear in an EV powertrain can improve performance, determining the appropriate number of gears for different vehicle applications remains a critical issue due to weight and space constraints. The additional complexities of a multispeed transmission system cannot be avoided. Therefore, optimization techniques for gear ratios, gear shifting strategies to minimize torque interruption during gear shifts, and the additional transmission losses will be thoroughly discussed and analyzed to explore advancements in EV transmission systems.

II. RELATED WORKS

A.

"Electric Vehicle with Multi-Speed transmission": A Review on Performances and Complexities by Md Ragib Ahssan, Mehran Motamed Ektesabi, and Saman Asghari Gorji, Swinburne University of Technology, Australia

This study thoroughly examines relevant literature to investigate the performance enhancements and complexities associated with multi-speed automatic manual/mechanical transmission (AMT) systems in electric vehicles (EVs). EVs equipped with multi-speed transmissions outperform those with single speed transmissions in terms of top speed, fast acceleration, and driving range. In an EV powertrain, the electric motor is the sole component responsible for generating torque, but its efficiency varies across a wide speed range. On the other hand, vehicles need to operate at different speeds under diverse driving conditions. The study demonstrates that a multispeed transmission system enables efficient operation of the electric motor by selecting the appropriate gear based on the torque-speed requirements, thereby achieving desired vehicle performance with minimal energy consumption.

”Powertrain architectures of electrified vehicles: Review, classification and comparison” by Guang Wu, Xing Zhang, Zuomin Dong

Stringent regulations and increasing consumer demand for fuel efficiency have driven the rapid development of various alternative powertrain solutions, particularly electrified vehicles. The integration of electric machines into powertrains has significantly expanded the range of powertrain architectures and provided new ways to save energy. This review work goes beyond the conventional classification of hybrid electric vehicles (Series, Parallel, and Power-split HEVs) and encompasses all electrified vehicles (xEVs) by introducing Pure Electric Vehicles (PEVs) as the fourth primary type of electrified powertrain architecture. Additionally, the level of electrification in the powertrain is analyzed and incorporated as a second index in the new classification method.

The review presents different variants of PEVs, Series, Parallel, and Power-split HEVs, along with corresponding patents or products. Furthermore, more complex electrified powertrains are illustrated by decomposing them into combinations of two or more of the four fundamental types and their sub-types. This comprehensive review is based on the late

"Modeling Of Electric Machines For Automotive Applications Using Efficiency Maps" by S. M. Lukic and A. Emado

The demand for improved fuel efficiency and the implementation of strict regulations have spurred the rapid advancement of alternative powertrain solutions, particularly in the field of electrified vehicles. By incorporating electric machines into powertrains, a wide range of powertrain architectures has emerged, offering innovative approaches to energy conservation. This review work expands upon the traditional classification of hybrid electric vehicles (Series, Parallel, and Powersplit HEVs) and encompasses all electrified vehicles (xEVs), including the introduction of Pure Electric Vehicles (PEVs) as a fourth primary powertrain architecture. Furthermore, the level of electrification within the powertrain is analyzed and integrated as an additional criterion in the new classification system.

The review explores various iterations of PEVs, Series, Parallel, and Power-split HEVs, providing details on corresponding patents or commercially available products. Moreover, more complex electrified powertrains are examined by deconstructing them into combinations of two or more of the four fundamental types and their respective sub-types. This comprehensive review is founded on a comprehensive and upto-date compilation of the latest advancements in the field of electrified powertrains.

"Comparative Studies of Drivetrain Systems for Electric Vehicles" by Wang, H., Song, X., Saltsman, B., and Hu, H.

Vehicle electrification is rapidly expanding in the next generation of passenger and commercial vehicles, contributing to enhanced energy efficiency. In the context of electric vehicle (EV) city buses, system designers are exploring various options, including direct drive and multi-speed gearbox architectures. The direct drive configuration simplifies the drivetrain system but necessitates a larger and more powerful electric motor. On the other hand, the multi-speed transmission system presents an opportunity to reduce motor size and optimize its operating points, albeit at the cost of increased complexity in terms of architecture and controls.

This paper offers an overview of several common system layouts and evaluates their respective advantages and disadvantages. Simulation results comparing the direct drive and multi-speed technologies are presented, considering factors such as gradeability, acceleration, and energy consumption. These results highlight the benefits of employing a multi-speed transmission in EV drivetrain systems over the direct drive approach, particularly for demanding city-bus duty cycles.

III. PROPOSED SYSTEM

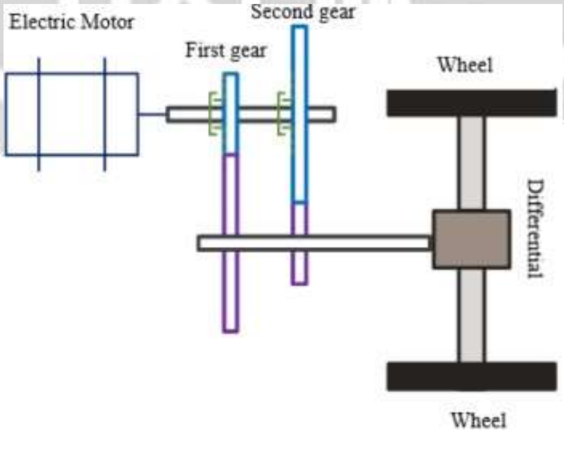
In electric vehicles (EVs), the transmission is directly connected to the traction motor to transmit the increased torque from the motor to the vehicle wheels. Therefore, it is essential to determine the location of the traction motor before discussing the different transmission variants in EVs. The powertrain can be classified into centralized drive and distributed drive systems based on the placement of the traction motor in the vehicle.

In a distributed drive system, the traction motor is directly connected to each individual wheel, often with a gear reduction in between. However, this study primarily focuses on the centralized drive system. The centralized drive layout in EVs resembles that of conventional internal combustion engine (ICE) vehicles, with the traction motor replacing the ICE and the battery replacing the fuel tank. In this drive mode, there can be one or two traction motors, and the transmission and differential or final drive occur between the motor(s) and the wheels.

The centralized drive system can have two major types of transmissions. The first is a single-speed or direct-drive transmission, where the transmission is directly linked to the traction motor to transfer torque to the wheels. The second concept is multi-speed transmission, which is a relatively new development in EVs. Previous research on EVs primarily focused on efficient traction motors, battery energy density, charging infrastructure, and other related technologies. Although commercially available EVs currently lack multi-speed transmission technology, researchers are exploring how this type of transmission system can enhance EV performance.

One type of multi-speed transmission is the continuous variable transmission (CVT), which can provide an infinite number of speeds based on driving conditions and help keep the electric motor operating efficiently. CVT operates using a special belt or chain and two pulleys located at a fixed distance. Metal V-belt drive and chain CVT drive are common forms of CVTs. By continuously changing the diameter of both the drive and driven pulleys, an infinite number of speeds can be generated.

In many articles, multi-speed transmission is referred to as automatic manual/mechanical transmission (AMT), and the same terminology will be used here. AMT is similar to conventional manual transmission, where the clutch plate is used to select a particular speed through a clutch pedal. The main difference is that AMT eliminates the need for a clutch pedal, as speed ratio changes in the gearbox are controlled by a set of sensors, speed controller, and actuator. The configuration of a two-speed AMT powertrain is shown. However, the AMT system offers more gear arrangements in EV transmission, which will be further explored in terms of performance.



The primary function of a gear train is to increase either torque or speed. By arranging the driver and driven gears in a particular manner, it can be determined whether the gear train will amplify torque or speed. To amplify output torque through a gear train, a power source is directly connected to a smaller gear, which then drives a larger gear. In the context of power transmission in electric vehicles (EVs), the motor is connected to the wheels. A clutch is used to couple the motor shaft to the gearbox, enabling engagement and disengagement between them. The output of the gearbox is connected to the differential through the propeller shaft. The differential then distributes power from the propeller shaft to both driving wheels, which are linked by half axles on each side.

Consequently, a gearbox is employed to adjust the effective torque and speed based on different driving conditions. For example, during start-off, a large gearwheel is utilized to provide greater leverage and generate the necessary torque to overcome inertia. However, it is possible to have a multi-ratio setup for an EV. By incorporating multiple gears, an EV can achieve improved acceleration at low speeds and potentially attain higher top speeds, which could also have a slight positive impact on its range. In fact, some Formula E race cars have implemented gearboxes with up to five speeds. A developed system is introduced, involving an electric vehicle with a manual gear system. The system incorporates the following features:

- Gear box
- BLDC motor
- Belt Drive
- Li-ion Battery

A. Gear box

To enable the engine crankshaft to rotate at a higher speed while the wheels turn at a slower speed, a device must be authorized. This device is enclosed within a metal box known as a gearbox. The gearbox plays a crucial role in transmitting mechanical energy in an engine to either increase the output torque or modify the motor’s speed. Gears are utilized to transfer power from one shaft to another, and the amount of torque transmitted depends on the size and number of teeth on the gears. Higher gear ratios result in greater acceleration but lower speed. Except for the main shaft gears, all the gears remain fixed in place, while the main shaft gears can slide in either direction along the shaft. If the gear ratio is greater than 1, the vehicle will experience increased acceleration and achieve higher speeds.

The working principles of a gearbox involve the utilization of gears of different sizes to cater to the varying torque requirements at the wheels based on factors such as road conditions, load, and terrain. For instance, vehicles that need to climb steep inclines necessitate higher torque compared to driving on a straight road. The design of the gearbox shift schedule has a positive impact on both the economic and dynamic performance of electric vehicles (EVs) by improving the motor’s working range. The efficiency of EVs and hybrid electric vehicles (HEVs) is greatly influenced by the gear shift schedule. By enabling motor controllability over a wide operating speed range and implementing a well-developed shift schedule, the need for clutches during gear shifting in multi-speed transmission systems for EVs can be eliminated.

However, gear shifting in such systems is associated with driving torque interruption and dynamic oscillation in the output torque to the vehicle wheels, which can affect vehicle comfort. Therefore, it is important to improve the shift quality, which is determined by torque interruption/ripple and shifting time. The overall efficiency of the EV powertrain is influenced by the selection of transmission gear ratios and the gear shift schedule. The performance of a specific motor is closely linked to the gear shift schedule and the selection of transmission gear ratios.

To achieve satisfactory EV performance and keep the motor operating at its highest efficiency zones, it is necessary to optimize both the gear shift schedule and gear ratios in combination. The gear shift schedule determines the gear selection based on driver inputs such as throttle angle and vehicle driving conditions, including vehicle speed. Shifting strategies are mostly determined based on achieving the lowest energy consumption, which is estimated by calculating the consumed battery energy in megajoules (MJ) or tracking the change in battery state of charge (SOC) over a complete drive cycle, such as the NEDC (New European Driving Cycle) or

UDDS (Urban Dynamometer Driving Schedule) FEATURES:

- To modify speed, either increasing or decreasing it..
- The torque output will vary inversely with the speedfunction.
- If the enclosed drive functions as a speed reducer.
- The torque output will experience an increase.
- If the drive increases speed, the torque output will decrease

B. BLDC motor

A brushless DC electric motor (BLDC motor or BL motor), also referred to as an electronically commutated motor (ECM or EC motor) or synchronous DC motor, operates using a direct current (DC) power supply. It employs an electronic controller to switch DC currents to the motor windings, generating magnetic fields that effectively rotate in space. The permanent magnet rotor of the motor follows these rotating magnetic fields. The controller adjusts the phase and amplitude of the DC current pulses to regulate the motor's speed and torque. This control system serves as an alternative to the mechanical commutator (brushes) found in many traditional electric motors. BLDC motors offer traction characteristics such as high starting torque and high efficiency, typically around 95-98Automakers today employ three different types of electric motors in green cars:

BLDC motors, brushed DC motors, and AC induction motors. BLDC motors consist of a permanent-magnet rotor surrounded by a wound stator. They are commonly used in electric scooters and electric motorcycles due to their affordability. For electric cars, 48V/60V/70V BLDC motors are designed, providing quiet operation without mechanical noise. Water-cooled brushless motors, with a rated torque of 10 Nm and a speed range of 30005000 rpm, contribute to the quiet movement of electric vehicles. The high starting torque and efficiency of BLDC motors make them the preferred choice for EV applications. Permanent magnet motors fall into two categories: sinusoidal fed permanent magnet synchronous motors (PMSM) and rectangular fed BLDC motors. Both types feature a permanent magnet rotor, with the difference lying in the winding of the stator. BLDC motors overcome the drawbacks of traditional DC motors, such as brush wear and tear, as they operate without brushes. Compared to induction motors, BLDC motors exhibit better efficiency and performance. Switched reluctance motors (SRM) are also utilized in EV applications due to the absence of permanent magnets, making them a popular choice.

C. Belt Drive

A belt drive is a power transmission mechanism that utilizes pulleys and an elastic belt to transfer power between two or more shafts. It primarily relies on friction to transmit power, although it can also function as a positive drive. Belt drives are capable of operating across a wide range of speeds and power requirements. Additionally, they are known for their high efficiency in power transmission. If you are looking for better performance, acceleration, motor cooling, and long distance rides, a belt-driven vehicle would be a preferable choice. However, it's worth noting that belt-driven vehicles can be more expensive to maintain and tend to generate more noise compared to hub motors. One drawback of using a belt drive on an electric bike is that it may limit the types of motors you can use. There are two main types of electric bike motors: mid-drive motors, which are positioned between the pedals in the center of the bike, and hub motors, which are located in the center of either the front or rear wheel.

Drives and drive control units for light electric vehicles play a crucial role in ensuring a safe and efficient riding experience. In a high-voltage hybrid vehicle, both the electric motor and the combustion engine contribute power to the powertrain.

When it comes to longevity, maintenance requirements, and noise levels, belt drives outperform chains. Belt drives have a longer lifespan, require less maintenance, and are significantly quieter than chains. In most gas-powered motorcycles, the noise generated by the engine and exhaust masks the noise produced by the chain. However, in quieter electric motorcycles, chain noise can be more noticeable and detract from the overall experience.

D. Li-ion Battery

Lithium and lithium-ion batteries are based on the highly reactive metallic element, lithium. These batteries are commonly used in two main applications: providing power to portable devices like cell phones, laptops, and MP3 players, as well as low-power, long-life applications such as memory elements and clocks.

Lithium-ion (Li+, Li-Ion, Lion) cells are typically employed as power sources for portable equipment and are rechargeable. They have largely replaced nickel-cadmium (NiCd or nicad) batteries and nickel-metal-hydride (NiMH) batteries as the dominant rechargeable chemistry in portable applications. Analog Devices offers a range of battery management products for these battery families, including chargers, fuel gauges, and smart battery components. Lithium-ion batteries are highly suitable for electric vehicles (EVs) due to their ability to undergo multiple recharge cycles, which is crucial for the extensive charge and discharge requirements of EVs throughout their lifespan. Additionally, the environmental impact associated with mining lithium-ion batteries has attracted significant attention.

Lithium-ion batteries, commonly used in smartphones, are widely employed in the majority of electric vehicles. The element lithium, known for its high reactivity, enables these batteries to store energy at high voltage and capacity, resulting in efficient and compact energy storage.

The demand for electric vehicles is increasing rapidly as part of the global effort to achieve net-zero emissions, with estimates suggesting the need for two billion electric vehicles.

However, the availability of lithium resources has become a concern. The rising demand for electric vehicles has put pressure on global lithium supplies, as lithium is a key component in EV batteries.

The sustainability and availability of lithium resources are important considerations in the ongoing development and adoption of electric vehicles. Efforts are being made to address these challenges and explore alternative battery technologies to meet the growing demand for electric vehicles while minimizing environmental impacts.

Lithium-ion batteries (Li-ion) possess several desirable characteristics such as high efficiency, a long cycle life, high energy density, and high power density. These features, coupled with their ability for rapid discharge, make them well suited for portable electronics applications.

CONCLUSION

This review article examined recent studies on the application of multi-speed transmission systems in electric vehicles (EVs). The gathered results were based on various motor capacities and vehicle sizes discussed in published articles. The primary objective of the review was to explore the different types of multi-speed transmission systems in EVs. While continuously variable transmission (CVT) is a popular choice, the article highlighted the importance of studying automated manual transmission (AMT) or similar systems, particularly for larger vehicles.

The review presented the performance of EVs with multigear systems using data from multiple published articles. The results demonstrated that multi-speed transmission systems can significantly improve both dynamic and economic performance in EVs. Compared to single-speed systems, multi-gear systems exhibited notable improvements in gradeability (up to 86

Most of the research related to passenger electric cars focused on two-speed transmission systems, with the main reason being the higher torque output of electric motors across a wider speed range, which reduces the need for additional gears in EVs. Several studies have examined the impact of adding extra gear parts to the transmission system and the resulting additional losses. One particular source of losses is the viscous shear in the wet clutch pack, which has been identified as the highest contributor to transmission losses compared to other sources. Another study focused on estimating the energy losses attributed to clutch friction, highlighting that friction work during clutch slipping is significant, particularly when smooth gear shifting or reduced torque interruption is desired.

Introducing a multi-gear system in electric vehicles (EVs) also poses a challenge in terms of cost. Although estimating the exact cost is a complex task, literature suggests that the total lifecycle cost of an EV equipped with a two-speed dualclutch transmission (DCT) could potentially be lower than that of an EV with a single-speed system. The additional costs associated with implementing a multi-gear system need to be carefully evaluated and weighed against the potential benefits in terms of performance and efficiency.

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