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SIMULATION OF POWER TRAIN DESIGN FOR THE EV APPLICATION – A REVIEW

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Abstract: A powertrain model is a simulation of the individual components of an electric vehicle propulsion system. It examines the interaction between electric motors, power electronics, batteries, and other auxiliary subsystems. The model uses mathematical equations and algorithms to provide insight into performance, efficiency and behavior. Engineers can use it to evaluate various factors, including battery capacity and engine specifications, and predict performance under various driving conditions. Powertrain models are useful tools for optimizing electric vehicle driving pleasure, energy efficiency and range.

INTRODUCTION

An electric powertrain, which converts electrical energy into mechanical energy, propels electric vehicles (EVs). Among its essential components are the electric motor, power electronics, battery pack, and control systems. Unlike traditional vehicles, electric powertrains propel themselves using electric motors and rechargeable batteries. The electric motor is the crucial component, converting electrical energy into rotating mechanical energy to generate a smooth and rapid acceleration. Power electronics control the flow of electrical energy by managing power transmission from the battery pack to the motor and enabling features like regenerative braking. The battery pack stores the necessary electrical energy, and technological advancements have increased energy density, range, and charging speed. Electric powertrains are made using the model-based design (MBD) method, which combines mathematical modelling, simulation, and optimization before physical implementation. By enabling engineers to create virtual prototypes, simulate various scenarios, and assess control strategies, MBD enables them to accelerate development cycles and optimize efficacy. It is essential for creating designs and incorporating cutting-edge elements for upgraded electric car technologies. The torque and power required to propel the vehicle are produced by the powertrain. The powertrain maximizes energy efficiency and increases the electric vehicle's driving range by effectively transferring power from the battery to the electric motor. Regenerative braking, which recovers energy during deceleration and stores it for later use, is also made possible by it. The control systems for the powertrain make sure everything runs smoothly, optimize power distribution, and improve performance all around. Importantly, the engine helps to promote sustainability by reducing tailpipe emissions and the environmental effect of the vehicle. In conclusion, the powertrain is essential for driving EVs, maximizing energy efficiency, and promoting environmentally friendly transportation. The powertrain generates the torque and power needed to move the vehicle. By efficiently transferring energy from the battery to the electric motor, the powertrain maximizes energy efficiency and extends the driving range of the electric car. It also enables regenerative braking, which captures energy lost during braking and stores it for later use. The powertrain's control systems ensure smooth operation, optimize power distribution, and raise overall performance. Importantly, the engine lessens the vehicle's environmental impact and tailpipe emissions, which supports sustainability. For driving EVs, optimizing energy efficiency, and encouraging environmentally friendly transportation, the powertrain is crucial. Typically, a review paper on the powertrains of electric vehicles (EVs) discusses a number of important points. In this review paper the significance of EVs and environmentally friendly transportation is highlighted in the beginning. The various battery technologies, power electronics systems, electric motor technologies, and battery management systems (BMS) are covered in the article. Additionally, it investigates thermal management, future trends, vehicle-to-grid integration, charging infrastructure, and control strategies. The main conclusions and probable future paths for EV powertrain research and development are summarized in the review paper's conclusion.

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LITERATURE SURVEY

Yamamoto, Kazusa, Matthieu Ponchant, Franck Sellier, Tommaso Favilli, Luca Pugi, and Lorenzo berzi et al.,[1]- The authors of this study, highlight the increasing demand for electric vehicles (EVs) due to stringent CO2 emission regulations and upcoming traffic restrictions on conventional cars in major cities. Their emphasis on the need for electrification in powertrain design has led to the emergence of hybrid and electric vehicles. The introduction of new mobility trends and consumers' desire for energy-efficient vehicles further accelerates the implementation of EV solutions. In particular, the authors discuss difficulties in torque vectoring, power management, and thermal comfort in electric vehicles. They provide control algorithms and strategies to optimize power flow and increase driving autonomy and range. The goal is to increase the efficiency of 48V EV powertrain designs by 20%. With Sim Centre Amesim TM technology, the Equivalent Consumption Minimization Strategy (ECMS) is put into practice.

Maryyeh Chehresaz et al., [2]- Reviewed a detailed discussion about When traditional internal combustion engine (ICE) vehicles were first introduced, electric vehicles (EVs) were seen as cleaner, quieter alternatives. Electric vehicles (EVs) run entirely on electricity, so they don't need fossil fuels and produce no noise or exhaust. However, electric vehicles have not yet become widespread due to high prices and limited range. Manufacturers have developed hybrid electric vehicles (HEV) and plug-in hybrid electric vehicles (PHEV) to bridge the gap between internal combustion engine (ICE) and zero-emission vehicles. To improve economy and increase cruising range, these technologies work by combining electric power with the internal combustion engine as a transitional technology. HEVs and PHEVs will serve as a bridge to all-electric vehicles until they become more widely available and bring more convenience to consumers.

Feyijimi Adegbohun 1, Annette von Jouanne 1, Ben Phillips 2, Emmanuel Agamloh 1 and Alex Yokochi et al., [3]- The study covers MATLAB/Simulink modelling and simulation of high-performance electric vehicles (EVs). It emphasises the expanding EV market as well as the advantages of EVs, such as improved performance, lower emissions, and higher efficiency. High-performance EVs are designed to address issues including cost, range anxiety, infrastructure for charging, and vehicle-to-grid operations while also enhancing safety on the road. For EV performance, health, and safety to be optimised under varied conditions, it is critical to comprehend how they operate. Discussed are various modelling methodologies and quality levels for modelling vehicles. The modelling of EV powertrains using MATLAB/Simulink is described as being flexible and supporting a range of configurations and add-ons. The main goal of the work is to build an equation-based model for a battery-powered electric vehicle (EV) in MATLAB/Simulink and to validate the findings through practical testing**.**

David Andrew Ord et al., [4]- The goal of Ord et al. (2014) aimed to develop a powertrain for Eco CAR 3 that meets performance and energy consumption targets. The "glider" model was used to assess the energy requirements of the driving cycle. MATLAB/Simulink component models are used to evaluate a variety of powertrain designs, including conventional, battery-powered, series-hybrid, and parallel-hybrid systems. Check the validity of the results using various modelling methods, including traditional vehicle models. Two of these evaluation techniques are one-step evaluation using an Excel spreadsheet and model-based design using a MATLAB-driven Simulink model. For comparison with the work presented in White's paper, a single-stage evaluation method was used (White, 2014). A powertrain model integrates various components to track energy losses as energy flows through the system.

Haotian Wu Purdue et al., [5]- The automotive industry places great emphasis on reducing greenhouse gas emissions, reducing dependence on gasoline, and improving energy efficiency, drivability, and safety. As a result, advanced and alternative drive architectures receive substantial research funding. Different models adopt different architectures, including power split, parallel direct connection, series connection, parallel connection, range extender and pure electric vehicles. There are both market products and prototype vehicles. Examples include the Toyota Prius, which introduced a power split design in 1997, the GM Volt, which introduced a range extender architecture in 2008, and the Tesla Model S, which introduced a high-performance all-electric powertrain in 2012.

Tade, Omkar, and Jyoti Kale et al., [6]- The transportation of people and products is significantly influenced by three-wheelers. Electric vehicles (EVs) are anticipated to overtake other forms of transportation in the future as the need for motorised transportation grows and the petroleum sector struggles to meet demand owing to the depletion of non-renewable resources. Additionally, lowering the complexity of after-treatment systems is a big problem for automobile manufacturers due to the strict emission standards in place around the world. The range, top speed, and gradeability of EV three-wheelers are frequently constrained when compared to traditional ICE vehicles. Performance is impacted by the extra weight of EV components, especially the battery. Modifying gear reductions, driveline components, and controller techniques are just a few examples of strategies that can be used in the powertrain design to get around these restrictions. These techniques can be used to improve the performance of electric vehicles so that it is on par with that of ICE vehicles.

Tran, Manh-Kien, Mobaderin Akinsanya, Satyam Panchal, Roydon Fraser, and Michael Fowler et al., [7]- Climate change is a pressing global issue caused by increasing greenhouse gas emissions. To combat this, the transportation sector

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is shifting towards electric vehicles (EVs) and zero-emission vehicles (ZEVs). Battery electric vehicles (BEVs) are gaining popularity, although the early stage of battery technology has led to the emergence of hybrid electric vehicles (HEVs) as a transitional solution. HEVs offer improved fuel efficiency and performance, addressing range anxiety concerns. Different forms of electrification exist, including mild hybrids, strong hybrids, plug-in hybrids (PHEVs), and BEVs.Research focuses on designing and optimizing electric powertrains using methodologies like planetary gear sets, topology modification, model-based frameworks, and multi-objective optimization. This study examines the design and optimization of an HEV powertrain, considering energy efficiency, emissions, safety, and consumer acceptability. Model-based design and simulation are used to develop and optimize the hybrid powertrain, including powertrain configuration selection and component sizing. Overall, this study provides insights into the process of developing an optimized HEV powertrain, utilizing advanced methodologies and software tools to electrify conventional vehicles.

Matheus F. Torquatoa, Kayalvizhi Lakshmanana, Ryan Poatter, Alexander Williamsa, Fawzi Belblidiaa, Ashraf A. Fahmya, c, Johann Sienza Alexander Williams et al., [8]- EVs are vital for reducing global emissions and achieving climate change goals. They are more efficient than ICE vehicles, with BEVs having a simpler design. However, optimizing BEV powertrains is challenging due to complexity and numerous variables. The industry aims to minimize costs of powertrain components while meeting performance constraints. Simulation tools are crucial for identifying cost-effective designs. YASA, a British electric motor manufacturer, contributes to emissions targets and efficiency improvements. Overall, computer-based simulations help overcome complexities in finding the optimal design for BEVs and facilitate the transition to electric mobility.

Daki Krishnachaithanya, Raghavendra Rao N S et al., [9]-This paper studies the effect of less well-known and affordably priced electric vehicles (EVs), in particular the Nissan Leaf and Ford Focus EVs, which are typically disregarded due to negative perceptions. The work develops an analytical model of the EV powertrain that incorporates both mechanical and electrical components in order to examine vehicle dynamics. The powertrain is composed of a motor, DC/DC converter, DC/AC inverter, battery pack, BMS, and control system. To determine how well the Ford Focus and Nissan Leaf handle on the road, real-world driving tests and MATLAB/Simulink simulations are conducted. There are tests for SOC, speed, motor torque, axle torque, and vehicle range comparison. Through the integration of modelling, testing, and analysis, this study investigates the driving behavior of these underappreciated EV vehicles.

Manh-Kien Tran et al., [10]- The use of fossil fuels in traditional cars has led to significant emissions from the transportation industry that have aided in the occurrence of climate change. When properly constructed, electric vehicles (EVs) can outperform conventional vehicles and offer a more environmentally friendly solution to this issue. This project's objective is to develop a powerplant that meets the performance requirements set forth by the Eco CAR Mobility Challenge competition. Breathing, accelerating, range, fuel efficiency, and emissions are all covered by these regulations. To evaluate the performance of five different powertrain designs and components, MATLAB/Simulink simulations were used. Only the P4 powerplant was ultimately able to meet all of the performance requirements. A 2.5 L GM engine and a 150 kW American Axle make up the vehicle. producing electronic drives for electric motor

CRITICAL REVIEW:

1) Challenges

Building an electric vehicle (EV) powertrain presents several challenges:

1. Battery technology: Electric vehicles rely on advanced and efficient battery technology. Developing batteries with higher energy density, longer life, faster charging and lower cost is a major challenge.
2. Range anxiety: EVs typically have limited range compared to conventional gasoline vehicles. Overcoming range anxiety through improved battery capacity and charging infrastructure is critical to widespread adoption.
3. Power and Performance: Developing an electric powertrain that can provide enough power and performance to match an internal combustion engine can be challenging. Key considerations are ensuring quick acceleration, high top speed and maintaining performance in all weather conditions.
4. Charging infrastructure: The availability and accessibility of charging stations play a key role in the practicality and comfort of owning an electric vehicle. Building a robust charging infrastructure network is a challenge that requires significant investment and coordination.

5. Cost: Electric cars can be more expensive than conventional cars due to the cost of batteries and other electronic components. Reducing the cost of electric powertrains while maintaining quality and performance is the challenge for automakers.
6. Weight and space constraints: Integrating batteries and electronics into vehicle designs while considering weight distribution, cargo space and passenger comfort presents challenges. Balancing these factors without compromising safety and functionality is critical.

2) DISADVANTAGES:

Lack of specific technology information: It is challenging to judge the viability and application of the proposed approach because the available material does not specifically indicate the technologies used in the study.
Limited in scope: This article focuses on the best powertrain design for 48V electric vehicles. It might not cover other crucial elements of the design of electric vehicles, like battery technologies, charging infrastructure, or general vehicle efficiency [1].

Absence of particular outcomes: Neither the offered information nor the quantitative data on the fuel consumption reductions that were made nor the overall performance of the optimized powertrain contain any specific outcomes.

Restricted range: The research focuses on power-split PHEV powertrain modelling and design optimization. It's possible that other crucial PHEV design factors including battery technology, charging infrastructure.

Technology restrictions: Other than the autonomies software, specific technologies employed in the research are not mentioned. The ability to judge the viability and applicability of the findings may be constrained by this informational gap [2].

Comprehensive technique: The paper outlines a process that encompasses modelling, simulation, and validation on a real-world vehicle system. With this strategy, the performance of the EV powertrain can be understood holistically, and the outcomes may be thoroughly analyzed.

Integration of simulation and real-world validation: The study acknowledges the complimentary functions of software simulation environments and real-world vehicle systems. The process blends modelling and simulation with real-world vehicle validation using MATLAB/Simulink software [3].

Complexity and Expertise: MBD techniques call for knowledge in simulation software, mathematical modelling, and design of control systems. Because of the method's intricacy, a highly qualified team and further engineering training may be required.

Model Accuracy and Validity: Reliable outcomes from MBD depend on the mathematical models' accuracy and validity. It might be difficult to create precise powertrain system models that include all pertinent dynamics and behaviors.

Model Validation and Calibration: Validating and calibrating mathematical models against real-world data can be a time-consuming and resource-intensive procedure. The accuracy of the simulation results significantly depends on how well these models are constructed [4].

Lack of Real-World Validation: Depending on the paper's content, there may be little to no real-world validation of the proposed methodologies. The findings may become less applicable or useful as a result.

Scope and Generalizability: The results of this article may be limited to the ideal all-wheel drive electric car and may not be readily transferable to other vehicle or engine architectures. [5]

Retrofitting Challenges: Retrofitting an existing 3-W vehicle with electric components may pose certain challenges, such as integration issues, space limitations, and the need for modifications to accommodate the new components. These challenges could increase the complexity and cost of the retrofitting process.

Cost: Retrofitting a vehicle with electric components can be expensive, especially when considering the cost of high-capacity Li-ion batteries and advanced electric motors like the PMSM. The initial investment required for the retrofit may be a barrier for some vehicle owners.

Limited Market Availability: Depending on the specific market and region, the availability of retrofit technology for 3-W vehicles may be limited. This could pose challenges in finding suitable components and service providers for the retrofitting process.

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Reliability and Maintenance: As with any complex system, electric vehicle components require regular maintenance and occasional repairs. The reliability and durability of the retrofitting components need to be considered to ensure long-term performance and reliability of the retrofitted vehicle. Access to trained technicians and appropriate servicing infrastructure may also be a factor to consider [6].

Validation and Real-World Testing: While software modeling and simulation provide valuable insights into powertrain design, the study acknowledges the need for further stages of model-based design research, such as software-in-the-loop and hardware-in-the-loop testing. These stages involve integrating the software models with physical components and conducting real-world testing to validate the performance and functionality of the designed powertrain. Without thorough validation, there may be uncertainties or discrepancies between the simulated results and the actual performance of the vehicle.

Limited Scope: The study focused specifically on the design of the powertrain for a hybrid electric vehicle, considering parameters related to performance, fuel efficiency, and pollutants. However, other aspects of vehicle design, such as chassis, body, suspension, and safety features, were not addressed in this study. To develop a complete vehicle design, further research and integration of these aspects are necessary [7].

Future Research Focus: While the study made significant progress in powertrain design using modeling and simulation, the authors mentioned that future research will concentrate on networked autonomous vehicles. This indicates a shift in focus towards autonomous driving technology, steering, acceleration, and braking with minimal human input. While this is an interesting area of study, it may divert attention and resources from further advancements in powertrain design and optimization [8].

Reliance on ML Model Accuracy: The ML-based model created to mimic the functionality of the proprietary BEV powertrain simulation program introduces an element of approximation or estimation. The accuracy of the MLVM model becomes crucial as it serves as the initial step in the cascade optimization process. If the MLVM model does not accurately represent the behavior and performance of the actual powertrain, it could lead to suboptimal results and potential inaccuracies in the final powertrain configuration [9].

Limited Generalizability: The ML-based model trained on a sample set of data points from the proprietary YVM may have limitations in terms of generalizability. The ML model's performance could be influenced by the specific characteristics and range of data used for training. If the ML model is not sufficiently trained or fails to capture the entire spectrum of powertrain behaviors, it may not accurately guide the optimization process, leading to suboptimal results.

Computational Overhead: While the cascade optimization method aims to reduce overall computation time by utilizing the MLVM model to identify an initial population of feasible solutions, there may still be a computational overhead associated with integrating multiple optimization stages [10].

CONCLUSION

Research studies on electric drivetrains for electric vehicle (EV) applications provide insightful information on a number of topics. On parts of the powertrain such electric motors, power electronics, and battery packs, they offer thorough information. Discussions of efficiency and performance analyses cover topics including power losses, energy usage, and regenerative braking effectiveness. Aspects of temperature management, range and energy management, and powertrain control algorithms are also investigated. In these publications, future trends and developing technologies are frequently highlighted. Examples include wireless charging, novel battery chemistries, and enhanced motor designs. Overall, reading these papers can help you better grasp electric vehicle powertrain design, optimization, and the most recent developments. The critical importance that powertrain components, design, and optimization play in enhancing performance and efficiency is highlighted in research articles on electric powertrains for electric vehicle. The benefits of electric powertrains over conventional internal combustion engines are highlighted, with a focus on things like improved efficiency, decreased emissions, and cheaper operating costs. By reading these publications, one can learn important lessons about improving the performance of the electric powertrain and comprehending its advantages over traditional engine technology.

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