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HYBRID ELECTRIC VEHICLES- A REVIEW

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Abstract- Unexpectedly, the notion of a hybrid electric vehicle has roots nearly as ancient as the inception of automobiles. Initially, the primary objective wasn't focused on reducing fuel consumption but rather on bolstering the performance of internal combustion engines (ICE). In the nascent stages, ICE engineering appeared more conventional compared to the burgeoning field of electric motor engineering. The debut of hybrid vehicles occurred at the prestigious Paris Salon of 1899, where manufacturers such as Pieper from Liège, Belgium, and Vendovelli and Priestly Electric Carriage Company of France showcased their innovations. These early hybrid vehicles marked a pivotal moment in automotive history, demonstrating the potential synergy between combustion engines and electric propulsion. While the primary aim wasn't explicitly aimed at fuel efficiency, the concept laid the groundwork for future advancements in hybrid technology. The integration of electric motors alongside ICE not only offered performance enhancements but also hinted at the prospect of reducing environmental impact, albeit in a rudimentary form compared to modern standards. As the automotive industry progressed, the focus on fuel efficiency gradually became more pronounced. Hybrid technology evolved to prioritize the optimization of energy consumption, with advancements in battery technology and electric motor efficiency playing significant roles. The early 20th century saw sporadic developments in hybrid vehicles, but it wasn't until the latter half of the century that significant strides were made in mainstream adoption. The oil crisis 11 of the 1970s spurred renewed interest in alternative propulsion technologies, including hybrids. Automakers began exploring 5 various hybrid architectures and refining their designs to strike a balance between performance, efficiency, and cost-effectiveness. However, it wasn't until the turn of the 21st century that hybrid vehicles truly gained traction in the market, driven by advancements in battery technology, stricter emissions regulations, and growing environmental awareness among consumers. Today, 2 hybrid electric vehicles have become commonplace, with a wide range of models available across various automotive segments. From

compact hatchbacks to luxury SUVs, hybrid technology has permeated every corner of the market, offering consumers an ecofriendly alternative without compromising on performance or convenience. Moreover, the continued evolution of hybrid systems, coupled with the rise of plug-in hybrids and electric vehicles, signals a promising future for sustainable mobility.

In conclusion, while the concept of hybrid electric vehicles may have originated over a century ago, its significance continues to resonate in the contemporary automotive landscape. What began as a modest attempt to augment ICE performance has blossomed into a transformative force driving the transition towards greener transportation solutions. As we look ahead, the legacy of those pioneering hybrid vehicles serves as a testament to the enduring quest for innovation and sustainability in the automotive industry. Keywords-Electric Motor, Batteries, Regenerative Braking, Hybrid Engine 1. INTRODUCTION Traditional vehicles with internal combustion engines (ICE) excel in providing impressive performance and extended operating ranges by leveraging the high energy density of petroleum fuels. However, they also suffer from drawbacks such as poor fuel economy and environmental pollution. These inefficiencies stem from various factors, including mismatches between engine fuel efficiency profiles and real-world operating conditions, energy dissipation during braking, especially in urban environments, and the low efficiency of hydraulic systems in stop-and-go driving scenarios.In contrast, battery-powered electric vehicles (EVs) offer several advantages over ICE vehicles, including high energy efficiency and zero emissions. However, they face challenges related to performance, particularly in terms of operating range per battery charge, which is typically less competitive than ICE vehicles due to the lower energy density of batteries compared to gasoline.Hybrid electric vehicles (HEVs) represent a hybrid approach, combining the benefits of both ICE vehicles and EVs while mitigating their respective weaknesses. By utilizing two power sources—a primary and a secondary power source—HEVs can achieve improved fuel efficiency, reduced emissions, and extended operating ranges compared to traditional ICE vehicles or pure EVs.In this chapter, we delve into the fundamental concepts and operational principles of HEV powertrains, exploring how they seamlessly integrate combustion engines and electric propulsion systems to optimize performance, efficiency, and environmental impact. 2 . CONCEPT OF ELECTRIC DRIVE TRAIN In essence, any vehicle powertrain must fulfill several key requirements: it must generate sufficient power to meet the demands of vehicle performance, store enough energy onboard to support driving within a given range, demonstrate high efficiency, and emit minimal environmental pollutants. Vehicles can have multiple energy sources and converters, such as gasoline or diesel heat engine systems, hydrogen-fuel cell-electric motor systems, chemical battery-electric motor arrangements, and more. When a vehicle incorporates [5] two or more energy sources and converters, it is termed a hybrid vehicle. Hybrid vehicles, by their nature, blend different propulsion technologies to achieve optimal performance, efficiency, and environmental friendliness. Specifically, [2] a hybrid vehicle that utilizes an electrical powertrain, consisting of energy sources and converters related to electricity, is referred to as a hybrid electric vehicle (HEV).

HEVs typically combine [9] an internal combustion engine (ICE) with one or more electric motors and a battery pack. The ICE can generate power either directly to drive the wheels or indirectly by charging the battery, while the electric motor(s) can provide additional power for propulsion and support regenerative braking, capturing energy during deceleration to recharge the battery. This dual-power approach allows HEVs [2] to operate in various driving conditions, optimizing fuel efficiency and reducing emissions compared to conventional vehicles .The integration of an electrical powertrain in HEVs enables them to leverage the benefits of electric propulsion, such as instant torque delivery, silent operation, and zero tailpipe emissions during electric-only driving modes. Additionally, [5] the ability to switch between power sources intelligently based on driving conditions further enhances efficiency and performance. Overall, [2] hybrid electric vehicles represent a versatile and sustainable solution for modern transportation needs, offering a balance between the convenience and range of traditional internal combustion engines and the efficiency and environmental benefits of electric propulsion systems. 3. ARCHITECTURES OF HYBRID ELECTRIC DRIVE TRAINS The architecture of a hybrid vehicle is loosely defined as the arrangement of components that dictate the flow of energy and control ports. Traditionally, hybrid electric vehicles (HEVs) [4] were classified into two basic types: series and parallel. However, it's worth noting that in 2000, some newly introduced

HEVs didn't neatly fit into these categories. As a result, HEVs are now 1 classified into four main types: series hybrid, parallel hybrid, series-parallel hybrid, and complex hybrid. These classifications encompass a range 5 of hybrid configurations that vary in how power is generated, distributed, and utilized within the vehicle. 1 A. Series Hybrid Electric drive Trains In a series hybrid drive train, the propulsion system relies on two primary components: an electric motor and an internal combustion engine (ICE). Unlike parallel hybrids where both the engine and motor can directly propel the vehicle, in a series hybrid, only the electric motor is responsible for driving the wheels. The typical setup of a series hybrid drive train involves the following components: 1. Fuel Tank: This stores the fuel, usually gasoline or diesel, which serves as the primary energy source for the vehicle. 2. Internal Combustion Engine (ICE): The engine is connected to an electric generator. Its purpose is to generate electricity rather than drive the wheels directly. 3. Electric Generator: The generator is driven by the ICE and produces electricity. This electricity is then used to power the electric motor. 4. Electric Motor: This is the primary power source for propulsion. It receives electrical energy from the generator and converts it into mechanical energy to drive the wheels. 5. Electric Power Bus: The output of the electric generator is connected to an electric power bus, which distributes the electrical energy to various components of the vehicle, including the electric motor.

6. Electronic Converter (Rectifier): The output of the electric generator is typically in the form of alternating current (AC), but the electric motor requires direct current (DC) to operate. 12 The rectifier converts the AC to DC, allowing the electric motor to receive the appropriate electrical input. In operation, the ICE runs at a relatively constant speed, optimizing its efficiency for power generation. The generated electricity is then used 3 to power the electric motor, which drives the vehicle. This setup allows for flexibility in how the ICE operates, 2 as it can run at its most efficient speed without directly impacting the vehicle's speed or acceleration. Overall, the series hybrid drive train offers advantages such as improved fuel efficiency, reduced emissions, and potentially quieter operation compared to traditional ICE vehicles. Additionally, it provides the possibility of using alternative fuels or power sources for the ICE, further enhancing the vehicle's environmental footprint. B. Parallel 6 Hybrid Electric Drive Trains In a parallel hybrid drive train, the vehicle's propulsion

system consists of two primary power sources: an internal combustion engine (ICE) and an electric motor. Unlike in a series hybrid where the ICE primarily generates electricity to power the electric motor, in a parallel hybrid, both the engine and the electric motor can mechanically drive the wheels, independently or simultaneously. 1. Internal Combustion Engine (ICE): Functions similarly to an engine in a conventional vehicle, providing mechanical power to the wheels through the transmission. 2. Electric Motor: Assists the ICE in providing power to the wheels. It 10 is mechanically coupled to the transmission, allowing it to directly contribute to propulsion. 3. Transmission: Transfers power from both the ICE and the electric motor to the wheels. It can be configured to allow for power from either source, or a combination of both, to be transmitted to the wheels. 4. Mechanical Coupling: The powers of the engine and electric motor are coupled together through mechanical means, such as gears or shafts. This allows for seamless integration of power from both sources and provides flexibility in how power is delivered 5 to the wheels. The mechanical coupling 1 of the engine and electric motor power allows for several different configurations, depending on the specific design of the hybrid system. For example: - In some parallel hybrids, 3 the electric motor can provide additional power during acceleration or assist the engine during high-load conditions, improving performance and fuel efficiency. - In other configurations, 1 the electric motor may be used primarily for regenerative braking, capturing energy during deceleration and storing it in the battery for later use. - Some parallel hybrids can also operate in electric-only mode at low speeds or during certain driving conditions, relying solely on the electric motor for propulsion and reducing emissions. Overall, the parallel hybrid drive train offers a flexible and efficient solution for powering vehicles, combining the benefits of both internal combustion engines and electric propulsion systems while minimizing their respective drawbacks.

4. CONCLUSION Hybrid-electric vehicles (HEVs) offer a unique combination of benefits from both internal combustion engines (IC) and electric motors, providing versatility in achieving various objectives such as improved fuel economy, increased power, or additional auxiliary power for electronic devices and power accessories. The power transmission systems in HEVs often utilize components like freewheels and chain wheels, which are cost-effective

and reliable. One of the main advantages of HEVs is their ability to optimize power delivery based on driving conditions. For example, during acceleration or climbing hills, both the IC engine and electric motor can work together to provide increased power and performance. Conversely, during cruising or deceleration, the electric motor can operate independently or assist the IC engine, enhancing fuel efficiency by reducing reliance on the engine alone. However, one drawback of HEVs is that driving solely on electric power may not be a practical option for long-distance travel due to limitations in battery capacity and charging infrastructure. Nevertheless, HEVs excel in stop-and-go traffic situations, where the regenerative braking capability of electric motors can capture and store energy that would otherwise be wasted, improving overall efficiency and reducing emissions. While HEVs typically have slightly higher upfront costs compared to conventional vehicles, they are more resourceful in terms of fuel consumption and emissions. Over the vehicle's lifespan, the savings in fuel costs and reduced environmental impact can offset the initial investment, making HEVs an attractive option for environmentally conscious consumers. In summary, HEVs offer a balanced approach to transportation, combining the benefits of IC engines and electric motors to meet various driving needs while reducing fuel consumption and emissions. Despite some limitations, advancements in hybrid technology continue to improve the efficiency, performance, and affordability of HEVs, making them an increasingly viable and sustainable choice for modern transportation.

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