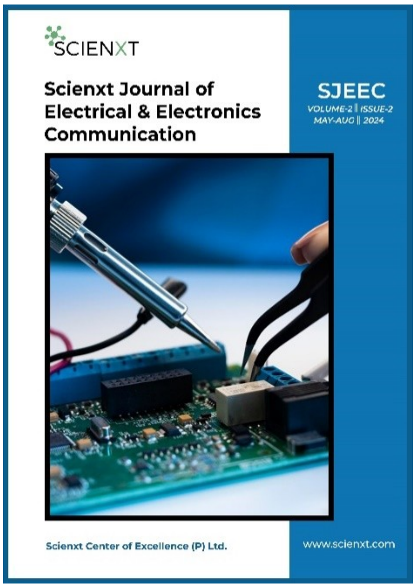

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Balancing battery and engine: A review of hybrid electric vehicles and their potential pitfalls

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Abstract:

In an effort to replenish the world's dwindling petroleum reserves, researchers are exploring a range of alter- native energy sources that might power hybrid vehicles. Because of the damage it does to the environment, using fossil fuels in vehicles is a major cause for concern. Various sources are being studied for potential use in automobiles, including batteries, fuel cells, super capacitors, and solar cells. Hybrid electric vehicles (HEVs) powered by renewable energy sources could be the way of the future when it comes to transportation. Power conditioning, energy management systems (EMS), and propulsion systems are just a few of the numerous components and techniques covered in this article that pertain to HEVs. Various other domains associated with HEVs are also discussed, including as automotive systems and DC machinery. A variety of models and techniques derived from experimental and simulation data are detailed. With the help of relevant references, the table provides a concise overview of the performance of various HEV system combinations. A number of scholars have compiled an exhaustive evaluation of HEVs, including all aspects such as EMS, source combinations, and models. While hybrid electric vehicles (HEVs) can be partially powered by present technology, more sophisticated systems and increased dependability are still required. This study has emphasized a number of problems, difficulties, and characteristics pertinent to the upcoming generation of hybrid vehicles.

1. Introduction:

Modern communities must place a significant premium on green technologies, particularly in their transportation sector. The quick expansion of today's contemporary cities has led to increased transportation demand that has resulted in vast pollution and other serious environmental concerns, such as climate change, smog, and acid rain1. Emissions from vehicles need to be managed, and aggressive efforts ought to be done to decrease these emissions. One method to do this is by employing alternative fuels and cars that have lesser impact on the environment. By decreasing fossil fuel emissions, such technology influences the environment favorably. However, hybrid cars still depend on fuel and emit some pollutants, which means they are not the final answer. The most urgent scientific problem now is the construction of near- zero-emission cars. Electric cars driven by renewable energy provide a viable answer since they create only natural results instead of exhaust emissions, improving metropolitan air quality and consequently the health of its inhabitants. Electric cars may be powered by various sources, such as batteries, super capacitors, or fuel cells. A fuel cell (FC) is one way for producing power that may be used to move automobiles. A FC is an electrochemical device that exploits a chemical reaction to create direct current (DC) electrical energy. This makes FCs more ecologically friendly and efficient than ICEs. One of the disadvantages of Fuel Cells (FCs) is their sluggish dynamic characteristics, which need the addition of other sources such as batteries and super capacitors (SCs). The disadvantage of batteries with high power density but low energy density is that they take longer to fully charge-between one and several hours. When it comes to voltage consistency, batteries out per form FCs. Batteries such as lead-acid, lithium-ion, and nickel- metal hydride are frequently used with FCs. Super capacitors (SCs) are an additional energy storage technology that may be used in conjunction with FCs. SCs have a low energy density and high self-discharge rates while having good power density and quick charging and discharging speeds.

Batteries could be charged during regenerative braking, which is a procedure that recovers part of the kinetic energy of the vehicle and slows its speed by utilizing an electric motor or generator. This manner, the energy that would normally be lost as heat may be utilized to charge the batteries and boost the fuel economy of the car. Batteries may also be charged by the residual energy of fuel cells (FCs) in low and no load power systems in the hybrid vehicle's energy management system. Fuel cells are devices that create energy by mixing hydrogen and oxygen in an electrochemical process. They may offer a constant and clean supply of power for the vehicle, but they also have significant disadvantages, such as high cost, limited durability, and delayed reaction. Therefore, hybrid cars employ a mix of fuel cells and batteries to maximize the performance and efficiency of the power system. The charge and discharge time cycle relates to the length and frequency of charging and discharging the batteries, which influences their performance and longevity. Sadly, batteries have a limited life cycle that is governed by the operating temperature (about 20 °C), the depth of discharge, and the number of discharge cycles [6]. The depth of discharge is the proportion of the battery's capacity that is utilized before recharging, and the number of discharge cycles is the number of times the battery can be completely charged and drained before its capacity decreases below a specified threshold. Lead-acid batteries are fairly durable, with a 1000 cycle lifespan, although they are not as long-lasting as Lithium-ion and Nickel-Metal Hydride (Ni-MH) batteries. These more recent models promise twice as long life, usually lasting 2000 cycles before needing to be replaced.

However, the advantages go beyond only endurance. Com- pared to lead-acid batteries, Li-ion and Ni-MH batteries have a substantially better energy density, which means they can store more energy per unit weight or volume. This leads to longer driving range for electric cars and lighter, more streamlined equipment for portable applications. Eliminate the need to carry heavy batteries around in order to charge your devices! These cutting-edge batteries also provide better response. Li-ion and Ni-MH batteries respond far faster to variations in current demands than the slow-moving lead-acid alternative. Current variations are fluctuations in the electric current that runs through the battery, which rely on the power consumption of the vehicle. Batteries that can react fast to current fluctuations may offer improved acceleration and deceleration for the vehicle. Super capacitors (SCs) have the potential to boost power in automotive applications as well. [4]. SCs are electro- chemical capacitors with a better power density than traditional kinds of storage. Power density is the amount of power that can be provided or absorbed per unit mass or volume of the device, and it impacts the speed and performance of the vehicle. SCs have an insulator that isolates and stores the electrical charges, as well as an electrical double layer. The electrical double layer is a thin layer of charge that arises at the interface between the electrode and the electrolyte of the SC. A little quantity of potential energy is provided by the separated charges, as low as 2-3 V. The resultant layer is made up of a micro porous material like activated carbon, which enhances storage density. Activated carbon is a kind of carbon that has a high surface area and numerous pores that may retain electric charge. SCs have capacitance values of up to 3000 F. Capacitance is the capacity of a device to hold electric charge, and it is measured in farads (F). Super capacitors, also known as ultra-capacitors, have various benefits over batteries, including a longer lifespan (500,000 cycles), a very quick rate of charge/discharge, and low internal resistance, which suggests reduced heat loss and improved reversibility [5]. Reversibility is the ability of a device to convert between charging and discharging modes without losing efficiency or capacity.

The progression of battery models, starting with a basic linear model that ignores internal resistance and state of charge (SOC). An enhanced model introduces a variable resistance to account for non-linear behavior like changes in SOC, yet neglects temperature's effect. The sophisticated numerical model incorporates internal resistance variations with temperature and SOC, along with overvoltage protections and volt- age/current spikes during charging/discharging. This complex model, recreated in BASIC code, offers a far more realistic and powerful representation of battery behavior. Essentially, by adding complexity and considering various factors, the model evolves from a simplified version to a highly accurate and dynamic representation of a real battery.

2. Discussion:

2.1. Electric vehicles:

Electric vehicles (EVs) are cars that employ an electric motor instead of a regular internal combustion engine (ICE). EVs function by transferring the electrical energy stored in the battery into mechanical energy via the motor. This energy moves the car, and while slowing down or stopping, the motor may operate as a generator, absorbing energy via regenerative braking. The energy gathered is stored in the battery for future use.

EVs have several downsides, which may restrict their acceptance or appropriateness for specific consumers. Some of the downsides of EVs are:

- Higher upfront cost: EVs tend to be more costly than conventional automobiles, mostly owing to the high cost of the battery and the motor. This may be a hurdle for certain prospective consumers, particularly in developing nations or low-income groups.
- Range anxiety: EVs have a limited driving range, which relies on the battery capacity, the driving conditions, and the availability of charging stations. Some drivers may have range anxiety, which is the dread of running out of power before reaching their destination or a charging outlet.

- Lack of charging infrastructure: EVs need a network of charging stations, which are not as broad or accessible as petrol stations. This might provide an issue for long- distance travel, remote locations, or places with inconsistent electrical supply.
- Long charging time: EVs require longer to recharge than conventional automobiles, which might take minutes to refill. Depending on the kind of charger and the battery state, EVs might take anywhere from 30 minutes to several hours to completely charge.
- Battery degradation: EV batteries deteriorate over time, decreasing their capacity and performance. This may impact the range, speed, and power of the EV, and may need replacement after a particular number of cycles or years. Battery replacement may be expensive and may cause environmental waste.

In conclusion, EVs are a promising technology that may provide a greener, cheaper, and more efficient alternative to conventional automobiles. However, they also face several obstacles, such as high upfront cost, restricted range, and lack of charging infrastructure, which may hamper their general acceptance or appropriateness for particular users. Therefore, it is vital to analyze the benefits and drawbacks of EVs before making a buying choice, and to consider the particular demands and preferences of each driver.

2.2. Hybrid electric vehicles:

Hybrid electric vehicles (HEVs) are automobiles that employ both an internal combustion engine (ICE) and an electric motor to power the wheels. They may operate on gasoline, electricity, or a mix of both, depending on the driving circumstances and the kind of hybrid system. There are many sorts of HEVs, such as mild hybrids, full hybrids, and plug-in hybrids, each with differing amounts of electric assistance and battery capacity [9].

Some of the benefits of HEVs are:

- They are more fuel-efficient than typical ICE cars, which means they consume less petrol and release fewer green- house emissions. Other HEVs can reach more than 50 miles per gallon, while other plug-in hybrids can travel for 20 to 40 miles on electricity alone.
- They are quieter than ICE cars, particularly in low-speed or stop-and-go traffic, when the engine may be shut off or assisted by the electric motor12.
- They frequently need less maintenance than ICE cars, since the electric motor minimizes the wear and tear on the engine and the brakes. The regenerative braking technology also recovers part of the energy that would otherwise be squandered as heat.

- They have superior resale value than ICE cars, since they are more popular and in demand among environmentally concerned and cost-saving buyers.

Some of the downsides of HEVs are:

- They are more costly than ICE cars, both in terms of initial pricing and repair expenses. The hybrid system adds complexity and weight to the vehicle, which raises the manufacturing and engineering expenses. The electric powertrain also needs specific knowledge and equipment to maintain and repair.
- They still create fossil fuel emissions, but less than ICE cars. The environmental effect of HEVs relies on the source of the power they utilize, which may vary from area to region. Some electrical systems are still dominated by coal or natural gas, which are neither clean nor sustainable sources of energy.
- They may have less power and performance than ICE cars, particularly in high-speed or difficult driving scenarios. The hybrid system may not be able to deliver enough torque or acceleration to fulfill the expectations of certain drivers. The battery capacity and electric range may also be restricted by the weather, topography, or driving habits.

3. Advantages and disadvantages of a hybrid electric vehicle:

3.1. Advantages of a hybrid electric vehicle:

- They emit lesser carbon emissions than traditional auto- mobiles, particularly when driving on pure electric mode.
- They have higher fuel economy than traditional automobiles, since the electric motor supports the engine during acceleration or low-speed driving.
- They have cheaper operating expenses than traditional automobiles, since they burn less oil and can be charged from a power source.
- They have better performance than traditional automobiles, since the electric motor offers an added boost of torque and power.

3.2. Disadvantages of a hybrid electric vehicle:

- Higher upfront costs: HEVs are more costly than normal automobiles owing to the complicated engine and battery system.
- Higher maintenance costs: HEVs need more specialized servicing and repairs for the electric components, which may not be immediately accessible or economical.

- Lower efficiency: HEVs may have less power and acceleration than ordinary petrol or diesel automobiles, particularly in highway driving situations.
- Limited battery life: HEVs have smaller batteries than plug-in hybrids or completely electric cars, which means they have less electric range and need to depend on the gasoline engine more frequently.
- The environmental impact: HEVs still emit some pollutants from the gasoline engine and the battery manufacturing, which may not be as eco-friendly as other options

4. Conclusion and implication:

Researchers have a keen interest in hybrid car systems powered by renewable energy sources like solar, wind, or hydroelectric power. Currently, only a handful of global projects focus on developing this technology, such as the Plug- in Hybrid Electric Vehicle (PHEV) Research Center at the University of California, Davis, and the Hybrid and Electric Vehicle Engineering Academy in Germany. This review article aims to comprehensively explore hybrid automobile technology, including its drawbacks such as high costs, battery degradation, and limited range. Simultaneously, researchers are actively seeking solutions to enhance the efficiency, durability, and performance of hybrid cars. Topics like renewable energy technologies and energy management systems have been extensively studied in previous research. Rather than isolating individual components like engines, batteries, or electric motors, various models and descriptions emphasize the holistic hybrid electric vehicle (HEV) system.

Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs) are poised to revolutionize the future of transportation, according to recent research. These vehicles have the potential to significantly reduce greenhouse gas emissions, fossil fuel consumption, and air pollution while offering economic and social benefits. Electromagnetic Systems (EMS) play a crucial role in optimizing the performance of hybrid power systems by efficiently managing velocity flows and coordinating various power sources like internal combustion engines, electric motors, and batteries. This not only enhances the hybrid vehicle's performance and energy conservation but also improves driving comfort and safety.

The incorporation of regenerative braking, facilitated by braking helicopters and staggered inverters, represents another advancement in energy-saving strategies for hybrid vehicles. Regenerative braking captures the kinetic energy during braking and converts it into electrical energy, reducing fuel consumption and brake wear. Essential components like power electronics converters and ion engines, in addition to the existing control system, are vital for the seamless operation and integration of hybrid vehicle systems. Power electronics converters control the electrical power's voltage, current, and frequency, while ion engines use electric fields to accelerate ions, generating thrust.

The scientific models of Hybrid Electric Vehicles (HEVs), successfully replicated by researchers, serve as valuable tools for comprehending the performance of hybrid vehicles. These models can simulate the behavior and dynamics of hybrid systems under various conditions, such as driving cycles, road profiles, and weather conditions. They play a crucial role in designing, optimizing, and evaluating hybrid vehicle systems and components. As technology advances, HEVs are likely to become the future of transportation. Ongoing scientific research focused on reducing manufacturing costs and improving the overall system holds the potential to drive growth in the HEV industry, increasing market penetration and customer acceptance of hybrid cars.

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