Electric Vehicles, Hybrid Electric Vehicles and Plug-In Hybrid Electric Vehicles

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Synopsis

Battery only vehicles or pure electric vehicles are those automobiles that are powered by electricity using several batteries to drive the electric motor. It should be understood that tailpipe emissions of EVs are equal to zero meaning that such vehicles are green. They use an external source of electricity and are known to provide a more silent and stabilize driving as opposed to those that use internal combustion engine (ICE) systems. This involves brands that are well known, such as the Tesla Model S and Nissan Leaf. The primary benefit is that the various models have expanded and are now capable of covering more than 200 miles on a single charge. However, challenges such as lack of enough charging facilities and other factors resulting in battery pull-out still exist.

Integrated Electric Vehicles (HEVs) or full power electric hybrid cars use both the internal combustion engines, electric motor and small battery pack. Powering of the battery is done by regenerative brakes system and the ICE in a way that it does not require external charging. As the name implies, hybrid electric vehicles (HEVs) are a design of vehicles that are efficient in fuel consumption and have minimal emissions. They can select between the electric motor and ICE or both based on the driving conditions without any intervention. Some widely recognized HEVs are the Prius manufactured by Toyota, and the Insight manufactured by Honda. Thus, HEVs deliver better fuel economy as well as reduced emissions in contrast to traditional vehicles, but they are, nonetheless, gasoline-based.

Hybrid electric vehicles – plug-in hybrid electric vehicles share features with both types of vehicles: evac as well as HEVs. PHEVs, in addition to their gasoline engines and electric motors, have much bigger battery stores than the HEVs, permitting PHEVs to travel independently on electric power for distances that vary between 20-50 miles. They can be connected to a socket in another power source for recharging. When the electric range is exhausted, vehicles are driven like standard hybrids, which are flexible drive systems. Such an ability is useful and contributes to staying mobile for a longer time or charging two separate vehicles at once. Such models exist in the Chevrolet Volt model and the Toyota Prius Prime model. PHEVs represent the middle ground – with the ability to drive electrically for daily, local use, while retaining the extra range and flexibility of a gasoline engine for longer, less often journeys.

In their entirety, EV, HEV, PHEV offer a wide range of choices to the consumer who needs to shift toward reduced emission vehicles and away from the traditional fossil based fuels mode of operation that these vehicles perfectly fit every consumer’s need in terms of driving conditions and demands.

INTRODUCTION

- Electric vehicles (EVs) are cars that run on electricity instead of traditional fuels like gasoline or diesel. They come in two main types: all-electric vehicles (also known as battery electric vehicles or BEVs) and plug-in hybrid electric vehicles (PHEVs). We often just call them electric cars or EVs, even though some of them still use a combination of electricity and liquid fuels. One cool thing about EVs is that they can provide instant torque, which means they have a lot of power right from the start. Plus, they offer a quiet and smooth driving experience. So if you're looking for a greener and quieter ride, an EV might be just what you need.

- All-electric vehicles don't have regular engines like traditional cars. Instead, they're powered by one or more electric motors that run on energy stored in batteries. To charge the batteries, you simply plug the vehicle into an electric power source. And here's a cool fact - they can also get charged up through regenerative braking. The best part is, all-electric vehicles don't produce any emissions from the tailpipe. However, it's worth mentioning that there might be some emissions associated with the production of the electricity itself.

- Now, let's talk about PHEVs. These vehicles use batteries to power an electric motor, but they also have a regular engine that runs on another fuel, like gasoline. To charge the batteries, you can plug the PHEV into an electric power source, just like with all-electric vehicles. But here's the interesting part - the batteries can also get charged by the regular engine and through regenerative braking. Depending on the model, PHEVs can drive purely on electricity for about 15 to 60+ miles. As long as the battery is charged, you can rely mostly on electricity for your everyday driving needs. The regular engine kicks in when the battery is running low, during quick acceleration, at high speeds, or when you need some serious heating or air conditioning. Even when the PHEV runs solely on battery power, it produces zero emissions from the tailpipe. And even when the regular engine is running, PHEVs tend to use less gasoline and emit fewer pollutants compared to regular vehicles.

KEYWORDS

Electric Vehicles (EVs): Battery Electric Vehicle (BEV),Zero Emission Vehicle (ZEV),EV charging infrastructure, EV range, Lithium-ion battery, Fast charging, EV incentives, Electric motor, EV adoption, Sustainable transportation, EV market trends, EV manufacturers, Regenerative braking, Autonomous electric vehicles, Electric vehicle policy.

Hybrid Electric Vehicles (HEVs): Hybrid synergy drive, Parallel hybrid, Series hybrid, Fuel efficiency, Low emissions vehicle, ICE (Internal Combustion Engine) hybrid, Hybrid technology, Mild hybrid, Hybrid powertrain, Start-stop system, HEV market, Regenerative braking, Hybrid vehicle benefits, Dual power sources, Energy management system.

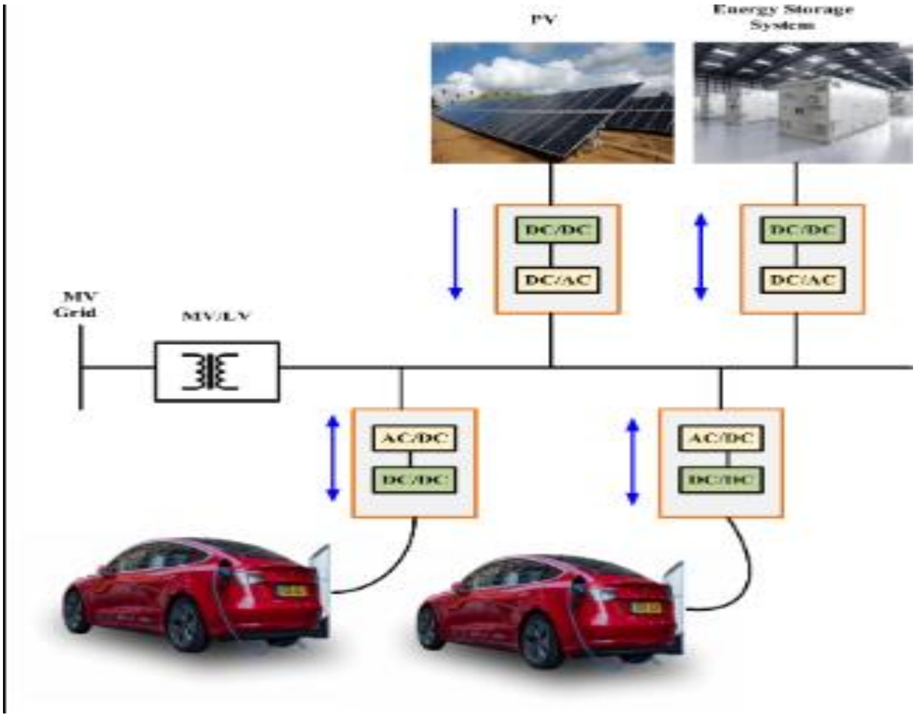
Plug-In Hybrid Electric Vehicles (PHEVs):PHEV charging, Extended range electric vehicle (EREV),PHEV incentives, Dual fuel vehicle, Battery capacity, Electric range, PHEV market trends, Plug-in hybrid technology, PHEV vs. HEV, Charge-sustaining mode, Charge-depleting mode, PHEV efficiency, Home charging station, PHEV emissions, PHEV advantages

Hybrid genetic algorithm-simulated annealing based electric vehicle charging station placement for optimizing distribution network resilience

To tackle the challenge of blending renewable energy sources with electric vehicle charging stations, our study introduces a cool new approach called the GA-SAA (Genetic Algorithm and Simulated Annealing). Unlike existing methods, our approach optimizes where to place EVCS in distribution networks, making the system more resilient and efficient. This study stands out by providing a comprehensive comparison with traditional methods, showing that our methodology performs better in reducing power losses and maintaining optimal voltage levels.

Offboard chargers are all about speed! They're designed for Level 3 charging, also known as DC fast charging. With this kind of charging power, EVs can juice up super quickly, sometimes in less than 30 minutes, and often reach 80% battery capacity. Offboard chargers are a crucial part of the EV charging ecosystem because they offer high-speed charging, meeting the needs of drivers who want convenient and speedy recharging options. When it comes to technology, it's common and practical to use an AC bus with multiple AC/DC conversion stages, especially when getting electricity from the regular AC power grids. But it's important to note that each conversion stage introduces energy losses, which can impact the overall efficiency of the system. Engineers and designers need to carefully consider the advantages of using AC technology while also finding ways to minimize these losses for top-notch performance. From an economic standpoint, opting for an AC bus with multiple conversion steps can have a big impact on infrastructure costs. Although AC technology is well-established and standardized, adding more conversion stages increases upfront expenses due to complexity and the need for extra parts. Organizations must weigh the initial costs against long-term benefits when implementing established technological standards.

The availability of AC switchgear and safety equipment directly affects the reliability and safety of an electrical system. It's crucial to protect the system against faults and ensure the safety of the staff using standardized methods and devices. These elements contribute to an overall stable and dependable electrical distribution system, which is essential for consistent operation and public safety. Increased energy losses in the system can have negative environmental effects, especially when electricity is generated from non-renewable resources. Higher energy consumption leads to higher costs and a larger carbon footprint. In applications where sustainability and reduced environmental impact are key considerations, minimizing conversion losses can be seen as a responsible environmental choice, aligning with the goal of creating a greener and more eco-friendly energy landscape. That's where DC-connected systems shine! They have streamlined electrical routes and fewer conversion stages, resulting in improved efficiency. This inherent efficiency is particularly beneficial for energy storage technologies like batteries, which are designed to operate on DC power.

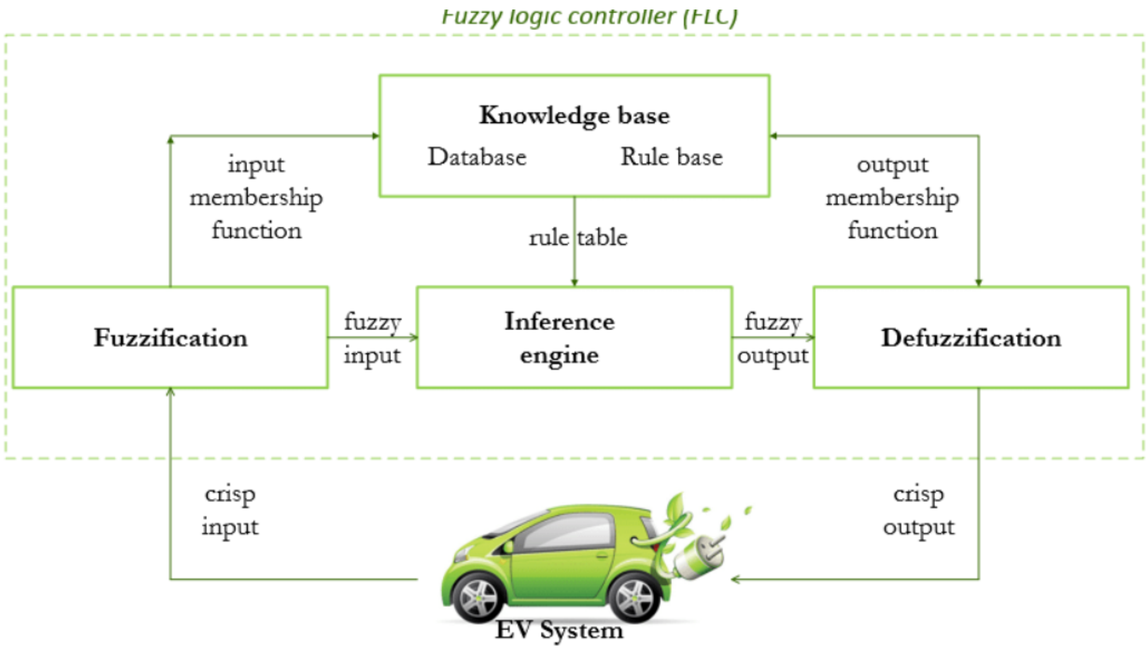


Reduction in energy loss, increase of efficiency, economy of scale in economic terms are among the many benefits of using DC connections. The costs of setting up a DC-connected system may be similar or slightly higher than those for an AC system that employ a conventional front-end converter at its center; however, this initial cost difference can easily be recouped through reduced losses over time coupled with simplified components during operation.

- Therefore, when it comes to long term projects within the energy sector, which require resilience against harsh environmental conditions, consideration must be given towards these aspects.Finally, but not least important point is that DC systems drive innovation forward by making it possible for breakthroughs in grid integration strategies as well as fast charging technologies
- Consequently, being able to adapt with such a rapidly changing sector like electricity generation makes them good fit solutions for up-to-date infrastructure demands

Fuzzy Logic Control

Fuzzy logic control (FLC) is an adaptive and non-linear control method that makes linear or non-linear plants more robust. The advantages of fuzzy RB methods are listed as follows: (i) robustness- they are tolerant to imprecise measurement sand component variations; (ii) adaptation- the fuzzy rules can be easily tuned if required . In line with the descriptions above, FLC suits as the EMS of HEV/PHEV. Its task is to decide how much power from the ICE and battery packs will be shared so that the engine runs at high efficiency or within a low emission zone . Also, for literature review purposes, reduction in fuel consumption and emissions is investigated where an FLC approach is applied for energy management of PHEV to figure out where the motor should operate along with specific points where the motor should be operated with respect to time. When this is done fuel use drops significantly not forgetting about such gases as HC, CO, NOx, and PM which also reduce substantially . Additionally, through an FLC-based torque controller designed for parallel HEV, ICE operational point can be set based on battery SOC required torque by ICE respectively .A lot of papers look at combining fuzzy control rules with other control methods or optimisation algorithms for better fuel economy and emission. To make the FLC strategy more effective particle swarm optimisation algorithm and GA are used in optimising membership functions of fuzzy controllers. These hybrid EMSs mentioned earlier apply only to particular driving cycle types thus becoming inadequate for all situations where they may be required. In order words different approaches should be taken into consideration when dealing with different conditions such as ANNs, driving cycle recognition machine learning algorithm etc., not just relying on one single solution but multiple ones that can adapt overtime. Nevertheless, similar to deterministic RB EMSs, the design process of fuzzy RB EMS is also based on the experience and intuition of human beings, and therefore it is difficult to ensure the optimal control performance.



Innovative plug-in hybrid electric vehicle comprehensive energy consumption evaluation method based on statistic energy consumption

According to the Theory of statistical energy consumption, which is the USUF Use in the US Energy Regulations Evaluation Indexes established actual fuel consumption of PHEV and described the distribution of PHEV fuel consumption. The energy consumption of PHEV includes fuel consumption and electricity consumption, both of them are calculated separately by the rules of regulations. This paper analyses fuel consumption and types of energy consumption based on two different views. The former is similar to calculation method for laws and regulations, hereinafter referred to as index 1The latter converts electric power into fuel finally expresses total energy cost with fuel. There are 8.9 kWh equivalent per litre gasoline mentioned as index 2Combining with driving mode selectivity assumption that in CD mode priority principle If it is determined to choose the rational vehicle usage mode according to the different travel mileage series shall be taken into account when considering hypothesis 2.

Index 1: calculation of fuel consumption

$$C = \begin{cases} 0, & D \leq \mathrm{AER} \\ \frac{D - \mathrm{AER}}{D} \cdot C_{\mathrm{cs}}, & D > \mathrm{AER} \end{cases}$$

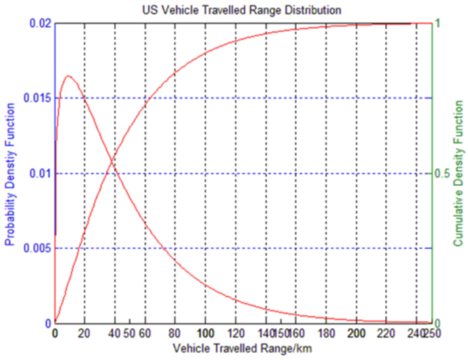
where C is the fuel consumption per 100 km (L/100 km); D is the vehicle mileage (km); AER is the all-electric range, PHEV pure electric driving range, the unit is km; Ccs is the fuel consumption per 100 km in the power holding mode, the unit is L/100 km.

Index 2: calculation of energy consumption

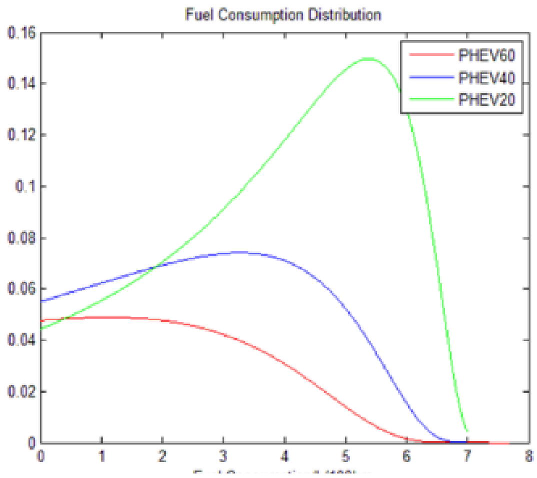
$$E_{a11} = \begin{cases} E_{\mathrm{CD}}/8.9, & D \leq \mathrm{AER} \\ \frac{\mathrm{AER} \cdot (E_{\mathrm{CD}}/8.9) + (D - \mathrm{AER}) \cdot C_{\mathrm{CS}}}{D}, & D > \mathrm{AER} \end{cases}$$

Where $Ea11$ denotes all energy consumption in L/100 km and ECD is the power consumption in power consumption mode, in kWh/100 km.

Probability density function of travel mileage distribution

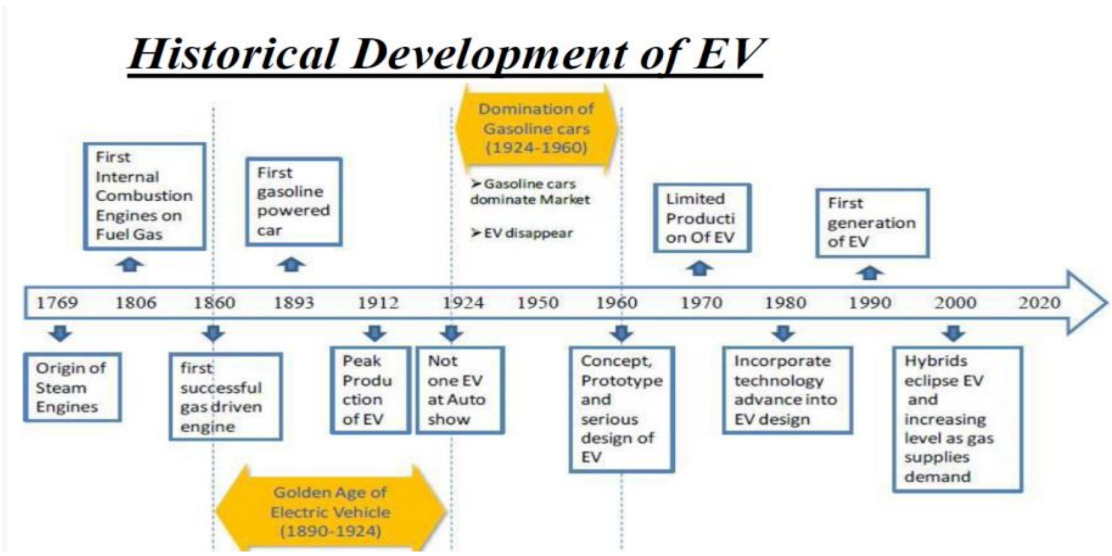


Probability density function of energy consumption



RESEARCH METHODS

In the early 1900s, electric vehicle was reserved for dignitaries likes Thomas Edison, John Rockefeller, Jr. and Clara Ford, the wife of Henry Ford due to its quiet ride over the vibrating and polluting I.C. engine.



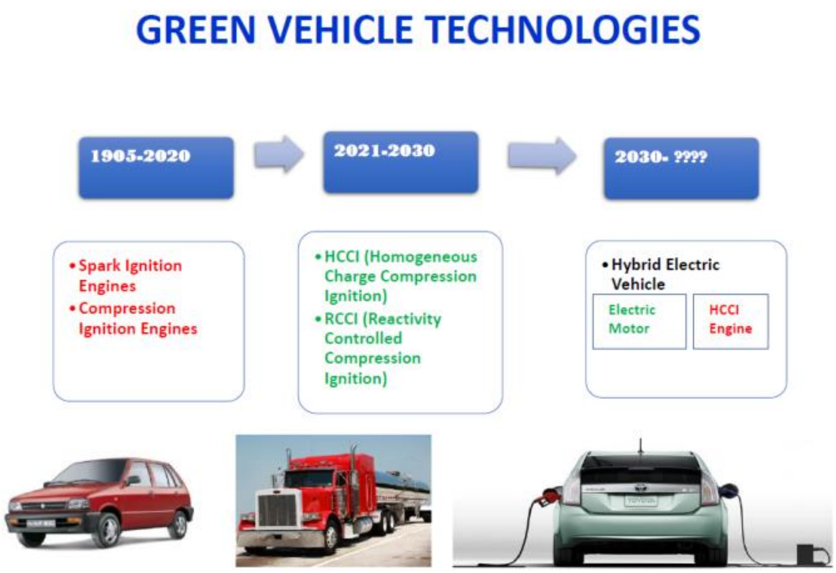
In 1769, Nicolas Joseph Cugnot and M. Brezin created the first steam-powered vehicle, capable of reaching speeds up to 6 km/h. This pioneering invention, although ground breaking, was notably heavy and had poor fuel economy. Additionally, it required a continuous supply of feed water to operate. Despite these limitations, Cugnot and Brezin's vehicle marked a significant milestone in the development of automotive technology.

In 1807, Francois Isaac de Rivaz developed the first internal combustion engine, which used a mixture of hydrogen and oxygen to generate energy. In 1825, Goldsworthy Gurney successfully completed an 85-mile journey in 10 hours with his steam car, demonstrating the practical potential of steam-powered transportation. These milestones significantly advanced automotive technology, showcasing the evolution from steam to internal combustion engines.

The evolution of automotive technology witnessed significant milestones across the 19th century. In 1839, Robert Anderson introduced the first electric vehicle, marking a crucial step towards sustainable transportation. The advancements continued in 1860 with Jean Joseph Etienne Lenoir's development of the first successful two-stroke gas-driven engine, revolutionizing the internal combustion engine's efficiency and reliability. By 1886, electric-powered taxicabs began to appear, showcasing the growing interest and viability of electric vehicles for urban transportation.

Between 1890 and 1910, the automotive industry saw the invention of hybrid vehicles, which combined internal combustion engines with electric motors, aiming to optimize fuel efficiency and reduce emissions. This period marked a significant innovation wave, blending the benefits of both gas and electric power sources to create more versatile and efficient vehicles. These early developments laid the groundwork for the modern hybrid and electric vehicles we see today, highlighting the enduring quest for improved performance, efficiency, and environmental sustainability in automotive engineering. Each innovation built upon the previous advancements, showcasing the relentless pursuit of better transportation solutions throughout the 19th and early 20th centuries.

From 1890 to 1924, electric vehicles experienced significant development and popularity, reaching peak production in 1912. However, by 1924, gasoline cars, which were far superior in terms of range and re-fueling convenience compared to their steam and electric counterparts, began to dominate the automobile market, maintaining this dominance until 1960. During this period, engineers recognized that combining the strengths of the gasoline engine, such as its high power and long range, with the advantages of the electric motor, like its efficiency and lower emissions, could result in a superior vehicle. This realization led to the development of hybrid automobiles, which merged the best features of both power sources. Hybrid vehicles aimed to offer improved fuel efficiency, reduced emissions, and enhanced overall performance, representing a significant innovation in the quest for better automotive technology.



Result And Discussion

Scope for improvements

There are many fronts where this technology can grow, be it in the adaptation, dissemination or penetration of HEV in the market. Being quite advantageous over conventional vehicles, it has some weaknesses in terms of efficiency, refueling, cost and many others. Some important thrusts of focus are listed below.

- **Battery issues** :The battery plays a vital role in HEV performance. They are quite heavy and expensive and thus impact the cost of HEVs. The performance of a battery is affected by temperature variations; therefore, an efficient battery management system is required. It needs long charging time and is sensitive to over/undercharge. Number of charge/discharge cycles decides the durability of battery. Further, disposal of toxic waste of battery is a big issue. Resolving these issues will allow the BEVs to run on the road.

- **Public awareness:** Public awareness and participation is very crucial to infiltrate HEVs in their lives. Various media and education can make people conscious about the advantages of this alternate transport. Participation of government, private players and cost-effective schemes will encourage consumers to use hybrid vehicles.

- **Smart charging infrastructure** :The charging infrastructure needs to be built at regular intervals so that these vehicles can be used for long journeys.

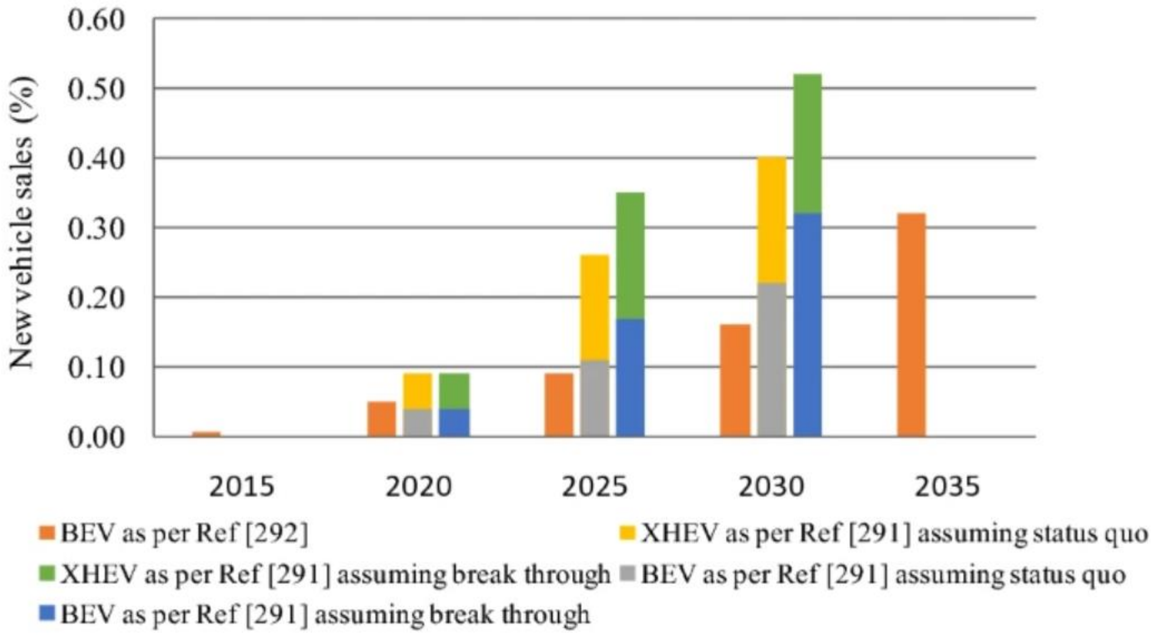
- **Impact on grid**: EVs and PHEVs mostly are charged by being plugged into the power outlet continuously for several hours. So, increase in these vehicles will increase the load on grid and power system performance issues. Hence, the need for extra generating units will arise. The electric power available in vehicles can also be banked at the grid using vehicle to grid (V2G) concept which is relatively unexplored at present. This concept works on the balancing of the ‘off-peak’ and ‘peak’ demands.

- **Cost** :Due to high prices of the batteries used in HEVs, EVs and PHEVs, these vehicles are not affordable to middle-income groups who comprise the major portion of the population. The advancement in control strategy, battery management system and less costly component utilization will decrease the purchase and operational costs which will attract more people to buy such vehicles.

Market share

According to , global sales of EVs have climbed from 1.2 million in 2017 to 1.6 million in 2018 and it has been estimated that it will rise to 2 million in 2019, 7 million in 2020, 30 million in 2030 and 100 million in 2050. The share of these vehicles globally is increased from 0.5% in 2014 to 1.7% in 2017. In 2017, China has 48% of market share and Europe has 26%. In terms of EV sales by country, China was once again the leader of the pack with over 600,000-unit sales, far ahead of USA which racked up 200,000.

It is expected that the penetration of EV/PHEVs will be around 35–47% of the new cars by 2040. It is observed that agencies have provided different statistics based on the growth rates, and thus, there are no unique data available on the long-term market share of these vehicles. The data on BEVs and XHEVs (including full HEVs and PHEVs) are taken from McKinsey and Morgan Stanley & Co. as they are the player in the vehicle domain statistics and the same is shown in Fig. 7. In , data are given for BEVs and XHEV for China, USA and Europe for status quo assumption and with breakthrough assumption till 2030, whereas in , the worldwide total data are given for BEVs till 2035. It can easily be inferred that the share of green vehicles will increase over the coming years.



1)Costs involved

According to a study of the University of Michigan’s Transportation Research Institute, the operating cost of EV is less than half of gas-powered cars. The average operating cost of an EV is $485/year as against $1,117 for gasoline-powered vehicles in the USA.

2)Maintenance costs

Changing the engine oil, coolant, transmission fluid and belts can add up in value over time. Since an EV does not have these parts, such repair costs are averted. The universal vehicle expenses, i.e., tire and brake changes, insurance and structural repair, are part of owning any vehicle. EVs are also not free of expenses. The highest maintenance cost associated with EVs is due to its battery which is unlike normal batteries. EV has large complex rechargeable batteries, which are quite resistant to any defect but degrade with time, and their replacement is quite expensive.

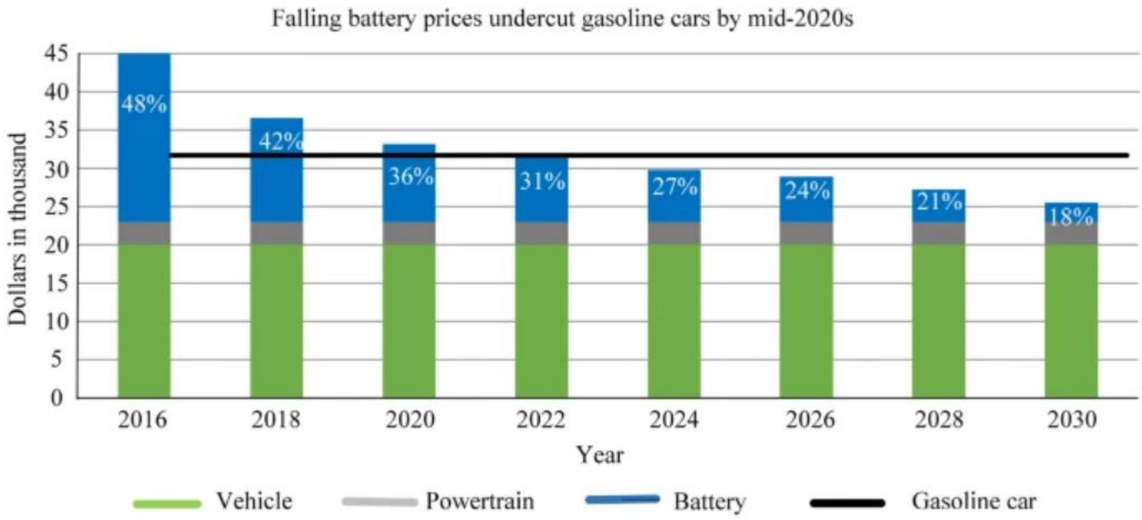
3)Electric car rebates and incentives

A great reason which attracts consumers to go for EVs is the country and state incentives available in the form of various subsidies and policies. These rebates help offset the typically higher cost of an electric car to make "going electric" more financially feasible.

Affordability

Since the production of the batteries has increased, its cost was shaved by approximately 50% and is expected to be lesser than $200/kWh by 2020. Improvement in battery technology will reduce the cost of the hybrid vehicle and make it accessible to more people. It is expected that EVs can be made affordable by 2022 even if the conventional cars improve their fuel efficiency by 3.5% a year. The analysis uses the US government's projected oil price of $50–$70 (£36–£50) a barrel in the 2020s. If the price is $20, the tipping point is pushed back between 3 and 9 years. Figure 8 depicts the battery pricings over the next 12 years, and it can be inferred that by 2022, EVs are likely to cost the same as ICE vehicle equivalent.

Fig. 8



Conclusion

HEVs are rapidly emerging as a potential alternative to the existing state of transportation due to their lower petroleum consumption and toxic emission. Strict CO_2 emission laws and increased public awareness will propel HEVs to be the future of road transportation. Penetration of PHEVs in the market will change the operations of electric grid substantially, and efforts are being made to provide a two-way communication between the user and the grid. A review of various components of HEVs like architecture, bidirectional converter, ESS, motors and MPPT has been presented, and the findings are summarized at the end of each topic in tabular form.

Based on the literature review, it is found that the complex hybrid architecture will provide greater efficiency, trading off on higher costs and more complex designs. As the inverters are needed to interface the motor engine with ESS, their selection is of prime importance and q-ZSI is found to be a promising candidate.

To extend the battery life, it is suggested to combine UC with battery which will further improve the fuel efficiency and performance during varying ambient conditions.

Based on the study carried out, it is observed that there is a growing interest in developing advanced traction motors for hybrid vehicles and many traction motors are available in the market. However, considering the trade-off based on performance, robustness, reliability and cost, the choice is often between induction motor and permanent magnet AC motor.

PVHEVs are still in infant stage and being explored to minimize gasoline consumption and maximize the usage of renewable energy. Various MPPT algorithms tuned with artificial intelligence techniques like FL, ANN and PSO are also being explored for PVHEV applications.

A comparison of various existing hybrid vehicles is provided in Table 9 which will serve as a guide to choose the best option. This paper provides all necessary information regarding the above-mentioned components and may be considered as a comprehensive document for the researchers and academicians who wish to carry out research in the field of hybrid vehicles.

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