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Optimization of Power train Architectures and Control Strategies for Hybrid and Plug-in Hybrid Electric Vehicles

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Abstract--|
Electric and hybrid electric vehicles (EV/HEV) are promising solutions for fossil fuel conservation and pollution reduction for a safe environment and sustainable transportation. The design of these energy-efficient power trains requires optimization of components, systems, and controls. Control sentail battery management, fuel consumption, driver performance demand emissions, and management strategy. The hardware optimization entails power train architecture, transmission type, power electronic converters, and energy storage systems. In this overview, all these factors are addressed and reviewed. A major challenge sand future technology for EV/HEV area is discussed. Published suggestions and recommendations are surveyed and evaluated in this review. The outcomes of detailed studies are presented in tabular form to compare the strengths and weaknesses of various methods. Furthermore, issues in the current research are discussed, and suggestions toward further advancement of the technology are offered. This article analyzes current research and suggests challenges and scope of future research in EV/HEV and can serve as a reference for those working in this field.

Keywords- *Architecture; electric motor (EM); electric/hybrid electric vehicle (EV/HEV); energy management strategies (EMSs); energy storage system (ESS).*

I. INTRODUCTION

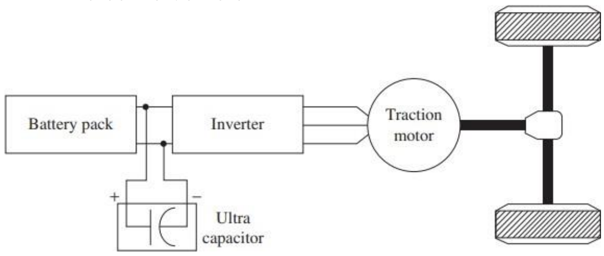
Conventional vehicles which use petroleum as the only source of energy, represent the majority of existing vehicles. However, the shortage of petroleum is considered one of the most critical worldwide issues, and increasingly costly fuel is becoming a major challenge for CV users. Moreover, CV s emit green house gases (GHGs), which means that it is becoming harder for them to satisfy increasingly stringent environmental regulations. One of the most attractive alternatives to CVs is electric vehicles (EVs) or zero-emission vehicles that consume electric energy only. However, owing to the limited energy densities of the commercial battery packs currently available, the performance of EVs is constrained to be being neighborhood vehicles with limitations of low speed, short autonomy and heavy battery packs.

Currently, hybrid electric vehicles (HEVs) are the most promising and practical solution. Their propulsion energy is usually from more than two types of energy storage devices or sources, one of which has to be electric. HEV drive trains are divided into series and parallel hybrids. Series hybrids are electric-intensive vehicles, because the electric motor is the only traction source and the internal combustion engine (ICE) merely works at its maximum efficiency, as an onboard generator to charge the battery. Keeping in mind the goals of creating an energy-wise, cost-effective and overall sustainable society, plug-in hybrid electric vehicles (PHEVs) have recently been widely touted as available alternative to both conventional and regular HEVs. PHEVs are equipped with sufficient on board electric power to support daily driving (an average of 40 miles per day)in an all-electric mode, using only the energy stored in the batteries, that is, without consuming a drop of fuel. This means that the embedded ICE uses only a minimal amount of fossil fuel to support driving beyond 40 miles, which results in reduced GHG emissions.[1]

II. Electric, Hybrid Electric and Plug-In Hybrid Electric Vehicle Topologies

Electric Vehicles Generally, EVs include electric motors for propulsion and ESSs, such as batteries, fuel cells, ultra capacitors, or combinations of these called hybrid energy storage systems (HESSs). EVs include not only electric cars but also other types of vehicles, such as electric bikes, electric boats, and electric airplanes and so on. Never the less, the focus of this chapter is mainly on electric cars. Thus, unless otherwise stated, when talking about EVs we mean electric cars. EVs that are supplied from batteries, which are the most common type, are called battery electric vehicles(BEVs).The very first BEVs were made in the mid-nineteenth century because of the operational simplicity of electric motors compared with ICEs, that is, the in here rotational movement of the shaft. However, over the decades, ICE cars replaced BEVs largely because of the low range of BEVs owing to low specific energy batteries. The main reasons behind the BEV concept nowadays is reducing environmental pollutants and reducing fuel consumption. As batteries are the main source of energy in BEVs, they should be sized accordingly to provide reasonable driving range and have low weight. To achieve this, many cells Should be put in series and parallel in a battery pack to provide a suitable voltage and power rating for running electric motors. Various issues should be considered in designing battery packs. The charging method of

Fig1Typical drive train layout of an all-electric vehicle



battery packs is an important factor from the aspect of battery pack life cycle, which will be discussed later in this chapter. A typical BEV drive train topology is shown in Figure 1 Generally, batteries have much lower specific energy compared with fossil fuels. Hence, to provide areas on able mileage range, very heavy battery packs are needed. Thus, as showing Figure 1, a high-power density ultra capacitor bank is required, in order to form a hybridized ESS. This gives an EV an added power capability in addition to energy capacity. However, the above- mentioned issues and some other reasons, such as a lack of charging infrastructure, currently make the options of HEVs and PHEVs more attractive. Nevertheless, battery technology is improving steadily and EVs are the ultimate transportation goal.[2]

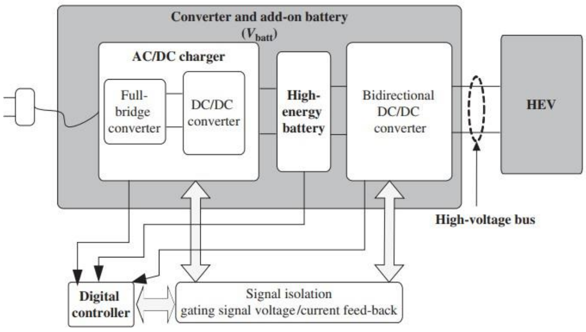
Hybrid Electric Vehicles

An HEV utilizes two or more sources of energy for propulsion, for example, gasoline, natural gas, hydrogen, liquid nitrogen, compressed air, wind, solar, electricity and soon. If one of these sources is electricity, this vehicle is called an HEV. This electricity can be provided by a battery pack, fuel cell and so on. HEVs generally combine ICEs with electric motors to run the vehicle. As mentioned earlier, HEVs may include vehicles other than cars; however, here we mean hybrid electric cars, which are the most common type. The main purpose of using HEVs, the same as with EVs, is to reduce the amount of emissions and fuel consumption, which can be achieved in different ways. The simplest way can be just turning the ICE off during idle times, for example, waiting at stop lights; this is called stop–start control strategy. Another idea is to convert the kinetic energy of the car to electric energy during braking, instead of wasting this energy as heat in the brakes. This can improvethemile-per-gallonrangebyupto15%.Thisfigureis increasing as the efficiency of the wheel-to-battery path components is improving. Different configurations of ICE and electric motor are possible in an HEV. They will be described in the following sections.[2]

***Plug-In Hybrid Electric Vehicles (PHEVs*)**

A PHEV is the combination of an HEV and an EV, which can be recharged using an electric plug. In fact, a PHEV benefits from both the hybrid nature of an HEV and the noticeable all- electric range (AER) of an EV. AER simply shows the distance that the PHEV or EV can cover using only the batteries. For instance, PHEV-30 means that the PHEVcan cover 30 miles on electricity alone. In a simple HEV, the AER is relatively small because of the small capacity of the battery pack. However, in a PHEV, the vehicle can run for longer on batteries alone. A typical layout of a PHEV is shown in fig 2

Fig2 Typical layout of a PHEV power system



The battery pack of a PHEV is much bigger and heavier than that in an HEV, in order that it can store the required amount of energy. The overall efficiency of PHEVs is much higher than ICE cars. The final usage price depends greatly on the price of electricity, because PHEVs require a relatively significant amount of energy to get charged. For example, charging a PHEV once per day approximately doubles the electrical energy consumption of a mid-sized home. Furthermore, the reduction of the number of pollutants depends on the source of electricity used for charging, that is, natural gas, hydro, and wind, solar and so on. PHEVs have three main topologies, which are the same as HEVs: series, parallel and series–parallel. Generally, PHEVs can operate in three different modes: charge-depleting, charge-sustaining and blended mode. If the battery has enough charge, the PHEV can operate using only electricity until it reaches the end of state of the charge; this is called charge-depleting mode. The battery pack cannot provide enough energy and power for acceleration if its state of charge (SOC) is low. In contrast, the battery pack cannot absorb available energy from regenerative braking if it is fully charged. Thus, it is desirable that the SOC of the battery pack is kept within a range, for example, 60–80%. If the control strategy operates the ICE and other parts to achieve this, it is called the charge-sustaining mode. In some PHEVs, the control strategy work s in such a way that for low speeds, for example, less than 60kmh−1, the vehicle works in charge-depleting mode and for high speeds, it works in charge-sustaining mode. This is called the blended mode. In other cases, the PHEV might operate in different modes for different speed ranges depending on the driving conditions and control strategy. This mode is called he mixed mode of operation.

III ELECTRIC VEHICLE—AN ALTERNATE MODE OF TRANSPORT IN INDIA

'Electric vehicles' (EV) are defined as vehicles that use an electric motor for propulsion. The electricity used to run the motor could come either through 'transmission wires', as is the case with electric locomotives, metro trains, and trams or through a 'single or a series of connected batteries', as is the case in electric bikes and electric cars, or it could be generated on board using a fuel cell. Again, battery-based EVs used in road transport include a large range of vehicles from electric two-wheelers, three-wheelers (rickshaws), cars, and electric buses. In this chapter, the term electric two-wheelers(E2Ws)is used for both electric bicycles and electric scooters while electric four-wheelers (E4Ws) is used for electric cars; E3Wis used to refer to electric three-wheelers(including E-rickshaws) and E bus to refer to electric buses. In addition, plug-in electric vehicles are classified into two types: battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). A battery electric vehicle (BEV) runs entirely using an electric motor and battery, without the support of a traditional internal combustion engine, and must be plugged into an external source of electricity to recharge its battery. Like all electric vehicles, BEVs can also recharge their batteries through a process known as regenerative braking, which uses the vehicle's electric motor to assist in slowing the vehicle and to recover some of the energy normally converted to heat by the brakes. The modern PHEV is a hybrid vehicle that is powered by an internal combustion engine and an electric motor. Batteries power the electric motor for the initial 'all electric range' of the vehicle. When the batteries run low, the vehicle continues to travel on the engine using fuels such as gasoline, bio fuels, natural gas, or hydrogen. Batteries can then be recharged whenever the vehicle is parked with access to any source of electricity.[3]

IV BENEFITS OF HYBRID ELECTRIC VEHICLE OVER ELECTRIC VEHICLE

Hybrid cars are powered by two engines: one petrol, one electric. Both work with each other to spin the wheels. This leads to lesser petrol being burned and therefore better fuel efficiency. When compared to conventional vehicles, hybrids offer better power and fuel efficiency as they combine the benefits of high fuel efficiency and low emissions. When hybrid vehicles are cruising or while braking, the result is excess power which is used to charge the batteries. This, in turn, aids higher fuel efficiency or range[4]

HYBRID VS. ELECTRIC CARS:

The main difference between a hybrid car and an electric car is that the hybrid combines an internal combustion engine and electric motor(s) to send power to its wheels. However, the electric car draws power from a single source of the electric motor(s) to propel the vehicle.

While hybrid cars offer better fuel efficiency or longer distances/ranges, electric vehicles are still yet to reach that potential. That said, electric vehicles pollute lower emissions compared to hybrid cars who are dependent on an internal combustion engine.

TABLE1.DIFFERENCE BETWEEN HYBRID AND ELECTRIC CARS:

Specifications	***Hybrid Cars***	***Electric Cars***
Power/Fuel Source	Electricity and Fossil Fuel (Petrol and Diesel)	Electricity Through Battery Pack(DC)
Engine	Internal Combustion Engine(ICE) and Electric Motor(s)	Electric Motor(s)
Fuel Efficiency	Combination of ICE and Battery Range	Depends on Battery Range
Emission Levels	Higher Compared to Electric Cars	Lower Compared to ICE and Hybrid Cars
Price Range	Similar to Conventional ICE Cars	High
Charging	Not Needed	Needed

KEY COMPONENTS OF HYBRID ELECTRIC CARS

Below are the main components which help generate power to propel the hybrid car.

INTERNAL COMBUSTION ENGINE

In a regular petrol engine, fuel is injected into the internal combustion chamber. Here, fuel mixes with air and is ignited by a spark plug.

ELECTRIC TRACTION MOTOR:

This motor draws power from the battery pack and sends power to the wheels.

Electric Generator:

This type of motor generates electricity from the regenerating energy while braking, which recharges the battery pack. Some electric generators act as both drive and regenerative functions.

TRACTION BATTERY PACK:

The pack stores electricity to power the electric motors and it also recharges through the electric generator.

The internal combustion of the petrol engine continues to remain the primary source of power to the hybrid car. The electric motor derives power from regenerative braking; however, the hybrid's battery pack cannot recharge without the primary petrol engine.

V. TYPES OF HYBRID CARS:

Automobile companies use different hybrid designs to either achieve maximum fuel efficiency or to keep the hybrid car prices as low as possible. Below are the different types of hybrid cars:

1) Parallel Hybrid:

In the most popular or common hybrid design, the parallel hybrid combines both electric and internal combustion engines to power the vehicle. They can run together or can be used as the primary power source while the other kicks in when extra power is required such as a hill climb, overtake a vehicle, etc. Both power sources are parallel connected to the gearbox or the transmission and hence they are called "parallel". An example of Parallel Hybrid Cars is the Toyota Camry, Honda Accord, Toyota Prius, Hyundai Sonata, etc.

2) Series Hybrid:

Under this type of hybrid car, the Series Hybrid also employs both the petrol internal combustion engine as well as the electric motor. However, the internal combustion engine does not propel the car, instead it generates electricity to recharge the battery pack. The battery pack in turn powers the electric motor(s) which in turns ends power to the wheels. An example of a Series Hybrid car is the BMWi3, Kia Optima, Ford Fusion, Chevrolet Volt, etc.

3) *Plug-in Hybrid:*

The Plug-in Hybrid elevates the conventional hybrid car with a much larger battery pack that requires to be charged. Generally, it uses a 110-volt electrical socket to charge the battery pack similar to an electric car. Since the Plug-in Hybrid car does depend on an internal combustion engine and can be run after it is fully charged, there is substantial improvement in the vehicle's fuel efficiency. An example of a plug-in hybrid car is the BMW 330e, Hyundai Ioniq Plug-in Hybrid, Volvo XC40 Recharge Plug-in Hybrid, etc.

4) *Two-Mode Hybrid:*

This type of hybrid design operates in two different ways. While on the first mode, it works just like a regular hybrid card. In the second mode, the design can adjust to different requirements by the engine to meet specific vehicle tasks.

5) *Mild-Hybrid:*

In recent times, the cost to build an efficient hybrid car continues to be high. Car companies are devising new strategies in offering hybrid technology to the common man. Mild-hybrid designs have been adopted by car companies to adhere to emission norms as well as to slightly improve fuel efficiency without increasing the cost considerably. In this type of hybrid, the electric motor assists the petrol engine in increasing fuel efficiency, improving performance or both. Additionally, it acts as a starter for the automatic start/stop function, which switches off the engine when the vehicle comes to rest and thereby reduces the use of fuel. An example of mild-hybrid cars Includes Maruti Suzuki Ertiga, Ciaz, Baleno, etc.

Advantages and Disadvantages of Hybrid Cars:

Hybrid cars may be a stepping stone before the automobile industry moves into pure electric vehicles. So, understanding the pros and cons of hybrid cars will help you understand the technology.

Pros of Hybrid Cars:

Cleaner Emission: Compared to the internal combustion engine, hybrid cars employ both electric and internal combustion engines. The result is reduction in emissions and is environmentally friendly.

Less Fuel Dependency: With an electric motor to support the primary petrol engine, there is additional power available. Hence, there is less dependency on fossil fuel.

Smaller and Efficient Engine: Since smaller engines don't have to power the hybrid car alone since there is an electric motor. Also, petrol engines used in hybrid cars are smaller in size and comparatively fuel efficient.

Regenerative Braking: Every time the brake is applied in a hybrid vehicle, the electric generator generates electricity and recharges the battery. This eliminates the need to stop the vehicle to charge the battery pack.

Cons of Hybrid Cars:

Lower Performance**:** Since the main motive is to increase the fuel efficiency or range of the hybrid car, the power or acceleration can lag behind a conventional internal combustion engine car.

Expensive to Buy**:** Although car companies are trying to bridge the gap in pricing between a conventional vehicle and hybrid, hybrids continue to demand higher costs.

High Maintenance Cost: With several mechanical parts in the cars and with two sets of engines powering the hybrids, the maintenance continues to be on the higher side. Also, not all mechanics are trained to repair a hybrid car.

VI. BENEFITS OF HYBRID ELECTRIC VEHICLE OVER ELECTRIC VEHICLE

Hybrid cars are powered by two engines: one petrol, one electric. Both work with each other to spin the wheels. This leads to lesser petrol being burned and therefore better fuel efficiency. When compared to conventional vehicles, hybrids offer better power and fuel efficiency as they combine the benefits of high fuel efficiency and low emissions. When hybrid vehicles are cruising or while braking, the result is excess power which is used to charge the batteries. This, in turn, aids higher fuel efficiency or range.

Past trend and current status of EV market in India

The current market for EVs is very small in India. Though there are different types of E2Ws (scooters and bikes), E4Ws (electric cars), and electric buses, the overall share of EVs is negligible (NationalElectricityMobilityMissionPlan2020, 2012). There are few market players (companies) in the EV sector in India. In the two-wheeler segment, Hero cycles, Electrotherm India, TVS Motor, and Hero Electric are manufacturing and selling electric two-wheelers. These electric two-wheelers are usually charged at the domestic supply voltage and, therefore, require no special adapter for charging the batteries. Normally, motors and other electrical kits for these vehicles are imported from China and other countries, whereas mechanical design and assembly of these bikes/two- wheelers are done here. In spite of a number of players selling these two-wheelers, the market share of these EVs is not large, primarily because of the high cost of the vehicle. However, recently, the off take of these vehicles has picked upon account of subsidy scheme launched by the Government of India and concessions given by some state governments (National Electricity Mobility Mission Plan 2020, 2012).

In case of electric three-wheeler segment, there are few established automobile manufacturers. The first electric three-wheeler (Vikram SAFA) was developed by Scooters India Ltd., Lucknow in 1996, and approximately 400 vehicles were made and sold. These vehicles ran on a 72V lead-acid battery system. The model was discontinued due to very less market demand. Mahindra & Mahindra Ltd. launched its first electric three- wheeler in 1999 including a new company named as MEML, based in Coimbatore, in 2001,to make and sell electric vehicles named Bijlee (National Electricity Mobility Mission Plan 2020, 2012). In 2004, MEML was closed down due to the lack of demand. However, Mahindra again started making electric vehicles at Haridwar plant in 2006 and continued to produce electric vehicles as per market demand. Bajaj Auto Ltd., Pune, had also demonstrated their three-seater electric rickshaw in 2001. However, this product has not been commercially launched (Shukla et al., 2014).

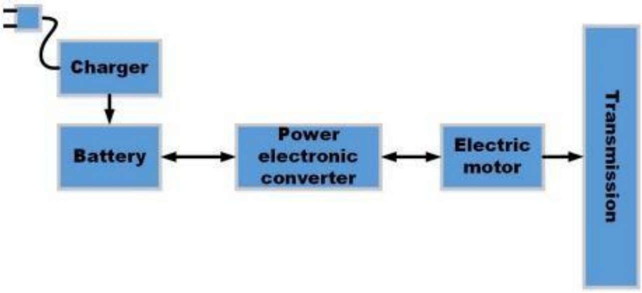
Fig3 Locally assembled electric rickshaws.

Fig 4 Variety of locally assembled e-rickshaws available in Indian market.

Recently, many of the major cities in India including Delhi, Hyderabad, Jaipur, Lucknow, and Kolkata have witnessed locally assembled electric rickshaws that have emerged as a popular mode for last-mile connectivity in these cities. Powered by electric motors and batteries, these electric rickshaws fall somewhere in between auto rickshaws and pedal-driven cycle rickshaws (see Fig.4).

VII. ARCHITECTURES OF HEV

Fig 5 EV architecture

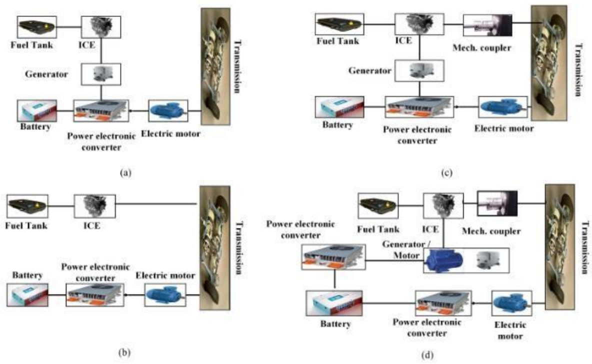


The HEV power train consists of two or more power plants. The ICE is the primary source of energy, responsible for producing most of the vehicle energy and long driving range, while the EM is the auxiliary source, responsible for high-vehicle-power demands and fuel economy of the ICE. The EM charges the batteries from the excess power from ICE when not needed by the vehicle and also from the regeneration of vehicle kinetic energy. The design and control of such powertrain require advanced control algorithms and EMS, which optimizes many objectives, such as the ICE fuel economy and the state of charge (SoC) of the batteries, with the system and driving constraints. The HEV system architecture consists of a drivetrain, ESS,and a controller unit. The integration of these components gives rise to various HEV configurations that are summarized as follows

1) Series HEVs: In the series configuration, the EM is responsible for providing the main traction force for the propulsion the vehicle. The ICE power is used to charge the batteries by a generator. The ICE–generator pair can also directly drive the traction EM without charging/discharging the battery. There is a benefit of traction flexibility by electrically de coupling the ICE from the drive shaft in this configuration, such as in diesel–electric locomotives. Operation modesof the

series configuration may be described as follows.
1) In the starting, both, the ICE and the EM deliver power for propulsion. 2) At light load, the ICE output is higher than required for the vehicle propulsion. This excess energy is used to charge the batteries. 3) During deceleration, the EM acts as a regenerative generator to charge the batteries. 4) At standstill, the ICE may be used to charge the batteries via the generator [1].
The series HEV can be considered an EV with an ICE battery charger, which gives the advantage of EV with extended driving range. The series configuration has the disadvantage of having the ICE, the generator, and the EM to drive the vehicle resulting in multiple mechanical– electrical–mechanical high- power conversions, with their associated conversion inefficiencies. This configuration is suitable for long-range and heavy vehicles, such as locomotives, with possible secondary electrical loads, such as in military vehicles.
Therefore, they are inherently large and expensive to address their high-power requirements. The series HEV can also give better performance in stop and go driving, such as city busses and large urban vehicles. Fig. 4(a) depicts a series-HEV configuration. The series HEV can have six different operation modes. 1) ESS alone. 2) ICE alone. 3) Combined Mode: Both ICE–generator set and the battery provide propulsion power.
4) Power Split Mode: The ICE–generator provides power to drivethevehicleandchargethebatteries.5)Stationary battery charging mode. 6) Regenerative braking mode. 2) Parallel HEV: In the parallel HEV configuration, the ICE and EM can additively supply power to drive the wheels. The ICE and EM are coupled to the drive shaft employing two clutches. The traction power is provided by either ICE or EM, or both. The EM can also serve as a generator, where it can regenerate the vehicle decelerating energy or be driven from the I CE when it powers in excess of that required to drive the wheels. Thus, the parallel configuration has two propulsion power sources: the ICE and the EM.

Fig 6 Various architectures of an HEV. (a) Series hybrid. (b) Parallel hybrid.(c)Series–parallel hybrid. (d)Complex hybrid



One advantage of this over the series configuration is smaller power ratings of these components, especially the EM, and the electromechanical power losses can be less. However, the parallel HEV can be less suitable for frequent stop-and-go urban driving conditions Fig. 6(b) depicts a parallel configuration of the HEV. Some operation modes of the parallel HEVareasfollows.1)EM alone. 2) ICE alone.

3) Combined
ICE-EM.4)Power Split: The power of ICE is split to drive the vehicle and charge the battery (EM becomes generator). 5) Stationary charging. 6) Regenerative braking. One other variation of the parallel HEV is called through the-road (TtR) HEV where ICE drives the front wheels, while the EM drives the rear wheels. Operation modes of the parallel configuration may be described as follows. 1) At the starting or full-throttle acceleration, both ICE and EM provide the power for vehicle propulsion. Typically, ICE and EM power sharing are80%and 20%, respectively. 2) During normal driving, the ICE supplies the propulsion power, and EM remains at standby. 3) During deceleration, the EM behaves as a regenerative generator and charges the battery.
4) Under light-load conditions, the ICE provides propulsion power and also charging power for the batteries through the EM that works as a generator.3) Series–Parallel HEV: The series– parallel configuration of HEV (power-split HEV) incorporates the advantages of both series and parallel HEVs. This configuration has the advantage of smaller size ESS and EM compared to the series and smaller ICE compared to the parallel configuration. Furthermore, the series and parallel modes are better efficient at low and high speeds, respectively. However, it suffers from higher system complexity and the addition of a planetary gear. Fig. 6(c) depicts a series–parallel HEV configuration. Being the hybrid system, a number of operating modes are feasible and are classified into two main categories: the ICE dominated and the EM dominated.Table1summarizes the operating mode. 4) Complex HEV: As the name suggests, this configuration is complicated. The complex HEV is similar to the series–parallel HEV, with the critical difference of having an additional bidirectional converter. The bidirectional converter provides for bi-directional power flow in the EM. This bi-directional power flow can provide for versatile operating modes, such as the combined ICE and two EMs. This configuration suffers from complexity and its associated costliness Fig. 6(d) depicts the complex configuration of HEV [1].
Operation modes of the complex configuration may be described as follows.

Table II Summary on ICE and EM Operating Modes for Series–Parallel HEV

	ICE dominating		EM dominating	
Modes of operation	Power for traction	Off condition	Power for traction	Off condition
At the starting	EM + BAT	ICE	EM + BAT	ICE
Full throttle acceleration	ICE +EM (ICE dominating)		ICE +EM (EM dominating)	
Normal driving	ICE	EM	ICE +EM	
Braking or Deceleration	EM acts as a generator to charge the batteries.		EM acts as a generator to charge the batteries	
Battery charging during driving	ICE and it also drives the generator to charge the batteries.		ICE and it also drives the generator to charge the batteries.	
Vehicle is at standstill	ICE drives the generator to charge the batteries		ICE drives the generator to charge the batteries	

1) During startup, the required traction power is delivered by the EMs, and the engine is in the OFF-mode.
2) During full-throttle acceleration, both the ICE and the EMs deliver power.
3) During normal driving, the ICE delivers power to the front wheel and to the first EM to charge the batteries.
4) During driving at light load, the first EM delivers the required traction power to the front wheel. The second EM and the ICE are in the OFF-state.
5) During braking or deceleration, both the front and rear wheel Ems acting combination as regenerative generators to charge the batteries.

VIII HYBRID ENERGY STORAGE FOR HEV & HESS:

A combination of two or more energy storage technologies. The main objective of HESS is to combine the high energy density of one storage technology with the high-power density of another. The end result can be higher combined power and energy density of the storage system, better vehicle performance, better fuel economy (HEV), and longer range (EV).

HESS With Ultra capacitors and Batteries

The energy source is the heart of EVs. Electro chemical batteries are the primary sources for EVs. However, the present-day battery technology does not adequately meet the vehicle for the high power, low cost, and high volumetric and weight energy densities [18]. Batteries also fall short in the required high charge/discharge power capabilities. Furthermore, the life span of batteries is inadequate at a high charge/discharge rate. However, the ultra-capacitors (UCs), characterized by high power density (about 5–10 kW/kg). However, the UCs cannot store a large amount of energy. Therefore, a promising solution may be to combine batteries with UCs forming a HESS. This can supply a high burst of power and also store enough energy to ensure an adequate driving range. Further hybridizing batteries with UCs will reduce the strain on the battery pack and potentially improve acceleration and hill-climbing performance. The UCs can also assist the battery in capturing regenerative braking energy with their fast-charging capability [1].

VIIII PLUG-INHYBRIDELECTRICVEHICLE STRUCTURE AND CONTROL METHOD

Structure of the PHEV shows the configuration of the plug-in series HEV investigated in this paper. The engine (E) consumes fuel (F) and drives an electric generator (G) to provide electric power to a power electronic converter (P) to supply common dc bus supplying the battery(B) and the driving electric motor
(M) through a motor controller(with in P). The motor is coupled to the wheels (W) through transmission (T).There is no direct mechanical connection between the engine and the wheels. The vehicle battery charger (Pc), which contains power electronic ac–dc converter, could be plugged into a source of electricity to charge t he battery as an alternative to using electricity from the engine-generator system.

PHEV Control Method There are several energy-management strategies for plug in vehicles, as classified in and In this paper, has propose a fuzzy-rule-based blended electric-dominant energy management strategy. The battery is charged mainly when the vehicle is plugged into the electricity supply network, which reduces fuel cost and potentially improves overall energy efficiency, if the electricity is supplied from a renewable source. An FLC uses the vehicle power demand and the BWS to determine the power split in a blended mode, which is similar to a charge-depleting mode but with power supplied mainly from the battery and assisted by the engine. When the BWS (and, hence, the SOC) reaches a set low level, the engine generator will take over from the battery as the main power source, with the battery meeting excess power peaks, i.e., the two sources operate together in a charge-sustaining mode. The BWS will be held near it slowest permissible level, storing just enough energy to meet the peak power demands [9].

Motor/Controller Model the characteristics of a permanent- magnet motor with a direct torque controller were used in the virtual vehicle simulator. Since the response time of the motor/controller, which is of the order of milli seconds, is much faster than the mechanical time constant of the vehicle and mechanical power train, the electric motor transient response could be neglected. The steady-state model based on the system output characteristics experimentally obtained

was therefore used Fig. 2 shows the output torque–speed characteristics and efficiency map of the motor/controller system. The output torque of the motor/controller system is determined by the driver's action on the pedal signal Aα.
Fig7.Engine maximum torque–speed characteristics

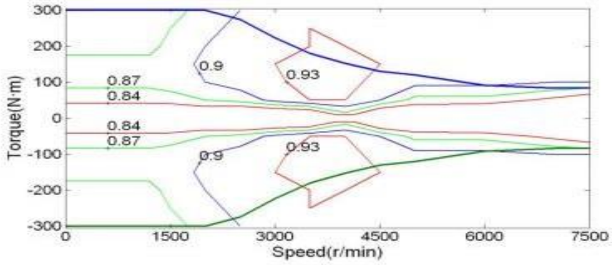
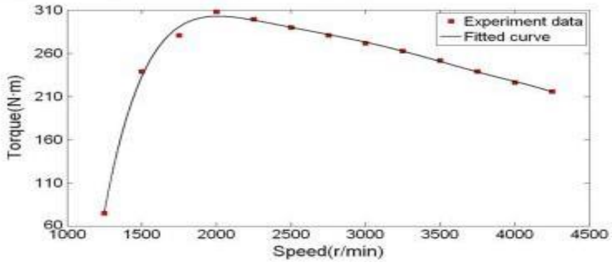


Fig. 2. Motor/controller output characteristics.



Aα >0 designates an acceleration command, and Aα ≤0 designates a deceleration command. The motor/controller sub system in the virtual model calculates the maximum output torque TMAX for the given angular velocity ωM and then calculates motor torque TM and power PM according the pedal signal, as given by TM=Aα TMAX (ωM) (4) PM=TMωM. (5)Power PM, i.e. ,the vehicle's drive power demand, determines battery power PB and generator power PG according to PM = (PB+PG)ηM,Aα≥0−PB/ηM, Aα<0.(6)The positive e vehicle power demand is provided by the battery and engine generator. Negative power is charged into the battery during regenerative braking.

X.CONCLUSION

This paper reviewed the fuel economy, drivability, and emissions are the main motivations for going to modern EV and HEV technologies. The HEV powertrain is more complex, in its architecture and control than the conventional and EV powertrains. This is mainly due to their two or more power sources, requiring optimal dynamic power split among them to achieve the best fuel economy. Power electronics, traction motors, and energy storage and recovery systems are the core technologies of EV and HEV power trains. Hybridization of the ESSs divides the requirements of high energy density and high- power density among two or more storage technologies, resulting in higher vehicle performance, longer range, and better fuel economies. Vigorous research and development, in the above areas, are being conducted in academic and industrial labs, internationally. The ultimate objective is to produce vehicle products that are preferable to conventional ICE vehicles in the marketplace. This will result in a natural transition to better automobiles and a healthier environment. This article presents the review of the different technologies of EVs consisting of BEVs, HEVs, PHEVs. The various architecture with their advantages and disadvantages have been elaborated so that one can choose the correct structure to work with and bring the best out of it. Various energy storage devices have also been discussed with their combination topologies. Numerous optimization strategies to control the flow of energy in the HEV powertrain have also been detailed. Several kinds of EMs for traction have also been discussed and compared. It is observed that the PMSM and IM are considered among the best options for traction applications. Power electronics of hybrid vehicles have also been presented with their merits and demerits.

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