Unit-V: ELECTRIC VEHICLES

Introduction to electric vehicles, principle, working and design of electric and hybrid vehicles, history of hybrid & electric vehicles, social & environmental importance of hybrid & electric vehicles, impact of modern drive trains on energy supplies.

HISTORY OF ELECTRIC VEHICLES:

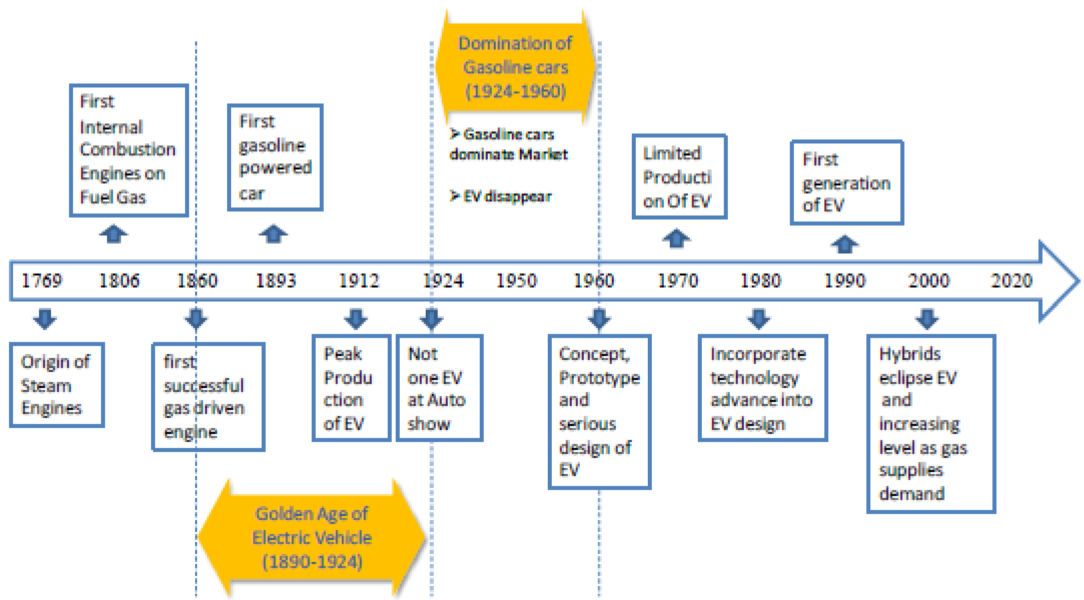
The first electric vehicle powered by non-rechargeable batteries was built in 1834, much before the development of IC engines. Electric vehicles were very popular during the 1890 to 1920 period despite their very high cost.

In 1912, EVs have reached their prime, making up nearly 28% of the cars on the road. The advances in IC engine technologies coupled with mass-production resulted in low-priced lightweight vehicles.

By 1920, the availability of cheap oil, electric starters, and a superior ability to travel long distances helped petrol cars to dominate the auto market and eventually led to the collapse of the EV market.

The downfall of EVs was attributed to a number of factors, including the need for long travel range, limited motor power and the easy availability of cheap petrol.

In 1945, three researchers at Bell Laboratories invented a device that was meant to revolutionize the world of electronics and electricity: the transistor. In 1966, General Motors (GM) built the Electrovan, which was propelled by induction motors that were fed by inverters built with thyristors.



During the 1960s and 1970s, concerns about the environment triggered some research on electric vehicles. However, despite advances in battery technology and power electronics, their range and performance were still obstacles. The modern electric vehicle era culminated during the 1980s and early 1990s with the release of a few realistic vehicles by firms.

History of Hybrid Electric Vehicles:

The concept of a hybrid electric vehicle is almost as old as the automobile itself. The primary purpose was not so much to lower the fuel consumption but rather to assist the ICE to provide an acceptable level of performance. In the early days, ICE engineering was less advanced than electric motor engineering.

The first hybrid vehicles reported were shown at the Paris Salon in 1899. The other hybrid vehicle introduced at the Paris Salon of 1899 was the first series hybrid electric vehicle and was derived from a pure electric vehicle commercially built by the French firm Vendovelli and Priestly. This vehicle was a tricycle, with the two rear wheels powered by independent motors.

Camille Jenatzy presented a parallel hybrid vehicle in 1903. This vehicle combined a gasoline engine with a electric machine that could either charge the batteries from the engine or assist them later. H. Krieger, built the series hybrid vehicle in 1902. His design used two independent DC motors driving the front wheels.

Other hybrid vehicles, both of the parallel and series type, were built during a period ranging from 1899 until 1914.

However, the greatest problem that these early designs had to cope with was the difficulty of controlling the electric machine. Power electronics did not become available until the mid-1960s and early electric motors were controlled by mechanical switches and resistors. They had a limited operating range that was incompatible with efficient operation. Only with great difficulty could they be made compatible with the operation of a hybrid vehicle. Dr. Victor Wouk is recognized as the modern investigator of the hybrid electric vehicle movement. In 1975, along with his colleagues, he built a parallel hybrid version of a Buick Skylark. The engine was a Mazda rotary engine, coupled to a manual transmission.

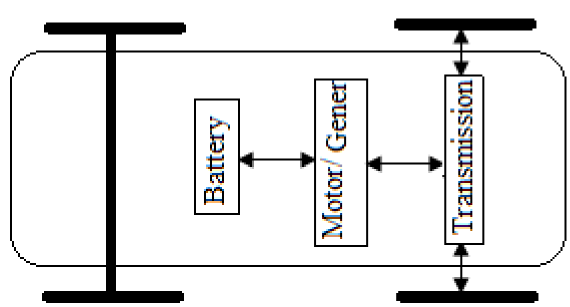
The series hybrid design was revived by Dr. Ernest H. Wakefield in 1967. Other approaches studied during the 1970s and early 1980s used range extenders, similar in concept to the French Vendovelli and Priestly 1899 design. These range extenders were intended to improve a range of electric vehicles that never reached the market. Other prototypes of hybrid vehicles were built by the Electric Auto Corporation in 1982 and by the Briggs & Stratton Corporation in 1980. Both of these were parallel hybrid vehicles.

The hybrid electric vehicle concept drew great interest during the 1990s. The most significant effort in the development and commercialization of hybrid electric vehicles was made by Japanese manufacturers. In 1997, Toyota released the Prius sedan in Japan. Honda also released its Insight and Civic Hybrid. These vehicles are now available throughout the world. They achieve excellent figures of fuel consumption.

Electric vehicles:

Electric vehicles (EVs) use electric motors for propulsion in place of conventional IC engines. Engine driven vehicles work on the principle of combustion get their energy from carbon based fossil fuels.

Working: The EVs have only battery as their energy source. It works on Faraday's laws electromagnetic induction principle. Basic structure of an EV is shown in Fig. The mechanical output is first converted into electricity using a generator. The converted electricity either charges the battery or can bypass the battery to propel the wheels via the motor and mechanical transmission. Major components of an electric vehicle include storage battery, drive motor, motor controller, power electronics converters, charge controllers and battery management system (BMS).



The EVs are classified as

(i) Battery Electric Vehicles (BEV) (ii) Hybrid Electric Vehicles (HEV).

Battery Electric Vehicles: Battery electric vehicles are propelled by electric motors by using energy stored on board in batteries. There are many similarities between an IC engine vehicle and a battery EV. To recharge the batteries of a BEV, periodically they must be plugged into an external source of electricity.

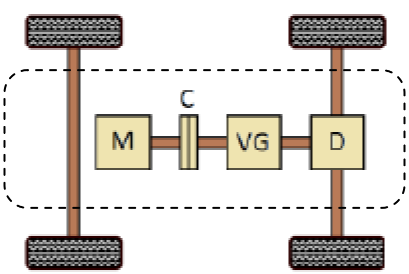
Hybrid Electric Vehicles (HEV): A vehicle that has two or more energy sources and energy converters is called a hybrid vehicle (HV). A HV with an electrical power train is called a hybrid EV. The sources of energy used in HEVs can be a combination of many resources such as battery, petrol, bio-fuels and fuel cells.

The EVs possess many advantages over conventional engine vehicles such as zero pollution, high efficiency etc., but they suffers from less travel range per battery charge than engine vehicles due to the lower energy content of batteries.

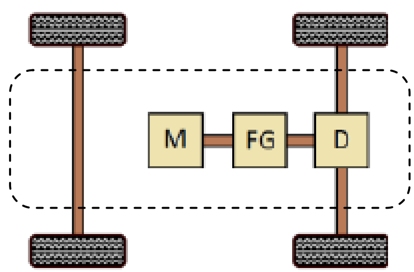
EV configurations/designs:

Based on the type of transmission, clutch, gearbox, differential and the number of motors, the EV configurations/designs are

a) The vehicles (as shown in figure (a)) with a clutch, a multi-speed gearbox and a differential. These EVs are modified versions of Internal Combustion Engine (ICE) vehicles with motors in place of engines.

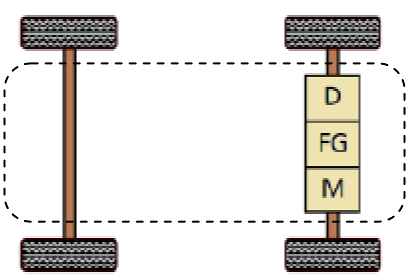


(a)

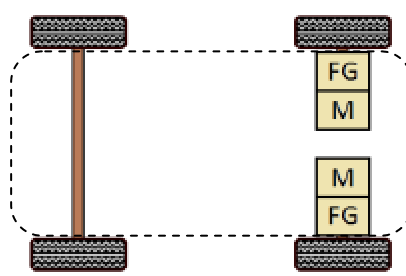


(b)

b) The EVs with a fixed ratio gearbox and a differential as shown in figure (b). They do not use clutch as the electric motor that has constant power in a long speed range. This resulted in reduced size, weight and increased driving easiness.



(c)

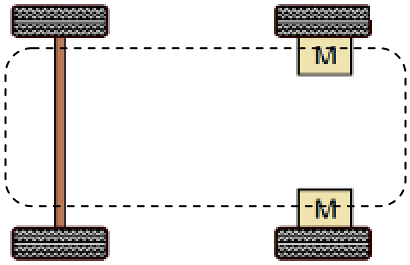


(d)

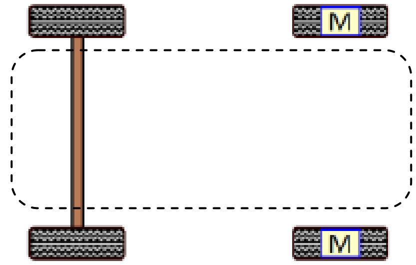
c) Similar to the drive train in (b) but the motor, fixed gearing, and the differential are integrated into a single assembly. Result is a further simplified drive train.

d) The differential is replaced by using two traction motors to drive front wheels as shown in figure (d) and operate at different speeds when the vehicle is running along a curved path.

e) The *in-wheel* drive with a thin planetary gear in which the traction motor is placed inside the wheel as shown in figure (e). The gear is used to enhance the drive torque.



(e)



(f)

C: Clutch, M: Motor, VG: Variable Gearbox, D: Differential, FG: Fixed Gearbox

f) Similar to the drive train in (e) except that the motor is placed inside the wheel without any gear. This design is relatively less complex than in (e).

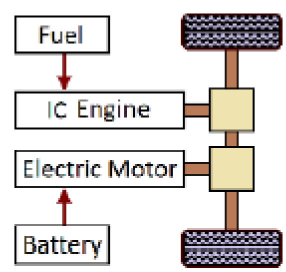
The latest innovation in electric vehicles is the in-wheel configuration. In this design, as shown in Fig. f, separate motors (known as in-wheel motors) are installed at each wheel. Mounting the motor and power electronics within a wheel assembly can improve efficiency, save space and give designers more flexibility in body design. It is possible to regulate drive torque and braking force independently at each wheel without the need for any complex transmission or drive shaft. Regenerative braking capability of in-wheels is very high, about 85%. This design will require drive motors with higher torque to start and accelerate the vehicle. In-wheel motors of capacity up to 75 kW is currently available.

The EVs possess many advantages over conventional engine vehicles such as zero pollution, high efficiency etc., but they suffers from less travel range per battery charge than engine vehicles due to the lower energy content of batteries.

Hybrid Electric Vehicles:

A vehicle that has two or more energy sources and energy converters is called a hybrid vehicle (HV). A HV with an electrical power train is called a hybrid EV. The sources of energy used in HEVs can be a combination of many resources such as battery, petrol, bio-fuels and fuel cells.

Working: An HEV typically houses a petrol engine with a fuel tank, a motor and a battery bank as shown in figure. The mechanical output is first converted into electricity using a generator. The converted electricity either charges the battery or can bypass the battery to propel the wheels via the motor and mechanical transmission. The main features of hybrid EVs are idle-off, regenerative breaking, power assist, electric-only drive, and extended battery-electric range.



On the basis of the degree of hybridization, hybrid electric vehicles can be classified as

(i) Micro Hybrid, (ii) Mild Hybrid and (iii) Full Hybrid

Micro Hybrid (µHV): Micro hybrid is the least electrified type of HEV. It is a conventional ICE vehicle with an oversized starter motor of about 3 to 5 kW at 12 V to assist the starting of IC engine. The motor cannot propel the vehicle, but can be used to assists accessories such as power steering and air conditioning. This type EV is generally used for frequent idle-stop or stop-start mode operations. During idling of a µHV, the engine is shut down and during regenerative braking; the motor works as a generator to charge the battery. Regenerative braking may not be in all µHVs. Micro hybrids usually have a hybridization factor of 5% - 10% with an energy savings of about 3% - 10% in city driving. µHV design is usually found in light vehicles, and is most suited for urban applications.
Example: Mercedes Smart.

Mild Hybrid (MHV): This hybrid uses motor of 7 to 15 kW at 60 to 200 V. Motor does not alone propel the vehicle but only supports starting of the engine, regenerative braking, and also provides supplementary torque when peak power is needed during acceleration. In MHV, the IC engine will be always running, unless the vehicle has stopped or the speed is very low as it is coming to a complete stop. The hybridization factor of mild hybrids is about 10% - 30%. Battery size is higher than micro hybrid. Energy savings in city driving is about 20% - 30%.

Example: Honda Civic and Honda Insight.

Full Hybrid (FHV): A hybrid EV which can move by electricity alone is a full hybrid. Since a FHV can run in *only electric mode*, it needs a large capacity motor, about 30 to 50 kW at 200 to 600 V. Energy saving is of the order of 30% -50%.

Example: Toyota Prius.

Hybrid electric vehicles have the benefits of both ICE vehicles and electric vehicles like *zero pollution, high efficiency long driving range due to the high energy-density of petroleum fuels etc.,* The drawbacks of Hybrid vehicle are

(i) More complex since it has two power trains.
(ii) These vehicles are more expensive besides increasing maintenance costs compared to both battery vehicles and petrol vehicles that rely on a single power train.

Designs/Architectures of Hybrid EVs:

Based on the way the energy converters (i.e. IC engine, electric motor etc.) of an HEV are combined to propel the vehicle, the major configurations of HEVs are

i. Series Hybrid (SHEV)
ii. Parallel Hybrid (PHEV)
iii. Series–Parallel Hybrid (SPHEV)
iv. Complex Hybrids (CHEV)
v. Fuel Cell Hybrids (FCHEV)
vi. Plug-in Hybrid Electric Vehicles (PHEV)

Series Hybrid EVs (SHEV)

In case of series hybrid system the mechanical output is first converted into electricity using a generator. The converted electricity either charges the battery or can bypass the battery to propel the wheels via the motor and mechanical transmission. The advantages of series hybrid drive trains are:

- Mechanical decoupling between the ICE and driven wheels allows the IC engine operating at its very narrow optimal region.
- Nearly ideal torque-speed characteristics of electric motor make multigear transmission unnecessary.

However, a series hybrid drive train has the following disadvantages:

- The energy is converted twice (mechanical to electrical and then to mechanical) and this reduces the overall efficiency.
- Two electric machines are needed and a big traction motor is required because it is the only torque source of the driven wheels.

The series hybrid drive train is used in heavy commercial vehicles, military vehicles and buses. The reason is that large vehicles have enough space for the bulky engine/generator system.

Example: Nissan e-Power.

Parallel Hybrid EVs (PHEV)

The parallel HEV allows both ICE and electric motor (EM) to deliver power to drive the wheels. Since both the ICE and EM are coupled to the drive shaft of the wheels via two clutches, the propulsion power may be supplied by ICE alone, by EM only or by both ICE and EM. The EM can be used as a generator to charge the battery by regenerative braking or absorbing power from the ICE when its output is greater than that required to drive the wheels. The advantages of the parallel hybrid drive train are:

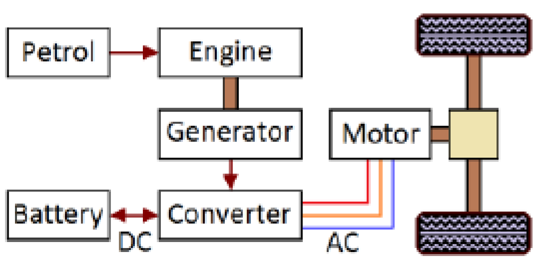
- Both engine and electric motor directly supply torques to the driven wheels and no energy form conversion occurs, hence energy loss is less.
- Compactness due to no need of the generator and smaller traction motor.

The drawbacks of parallel hybrid drive trains are:

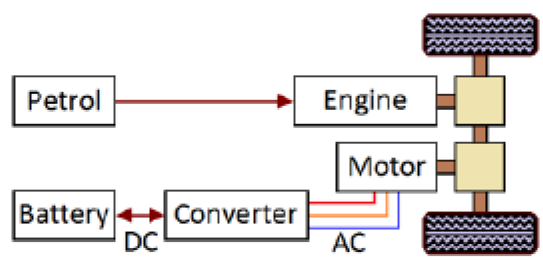
- Mechanical coupling between the engines and the driven wheels, thus the engine operating points cannot be fixed in a narrow speed region.
- The mechanical configuration and the control strategy are complex compared to series hybrid drive train.

Due to its compact characteristics, small vehicles use parallel configuration. Most passenger cars employ this configuration.

Example: Honda: Insight and Civic.



(a) Series Hybrid

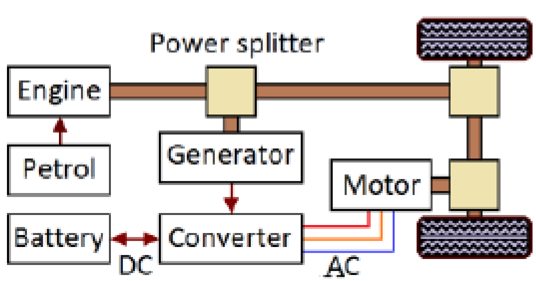


(b) Parallel Hybrid

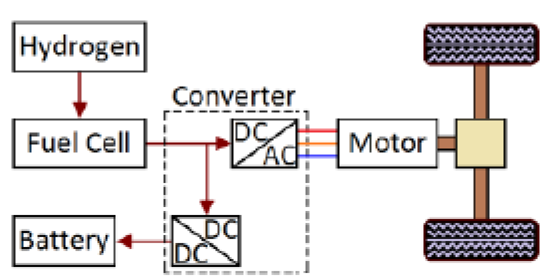
Series-Parallel Hybrid EVs (SPHEV)

Series–parallel hybrids (or power-split hybrids) combine the benefits of both series and parallel architecture. The power-split device divides the output from the engine into mechanical and electrical transmission paths. This design is capable of providing continuous high output power as compared to series or parallel power train. They use smaller motors. Series-parallel hybrids can achieve similar operating modes as series hybrid vehicles. However, it requires very complex control system.

Example: Toyota Prius.



(c) Series-Parallel Hybrid



(d) Fuel Cell Hybrid

Fuel Cell Hybrid EVs (FCHEV)

A fuel cell (FC) HEV is a series hybrid configuration in which fuel cell is the energy conversion system and a battery (or a super capacitor) is the energy storage system to deliver peak acceleration power. The operating principle of fuel cells is the reverse process of electrolysis in which hydrogen and oxygen gases combine to generate electricity with water and heat as by products. FC vehicles are true zero-emissions vehicles as they do not emit any greenhouse gases. Since fuel cells can offer high specific energy but cannot accept regenerative energy, it is usually combined with battery or other storage systems. At present, FCHEV technology is very premature and they are very expensive as compared to other HEVs.

Example: Honda Clarity.

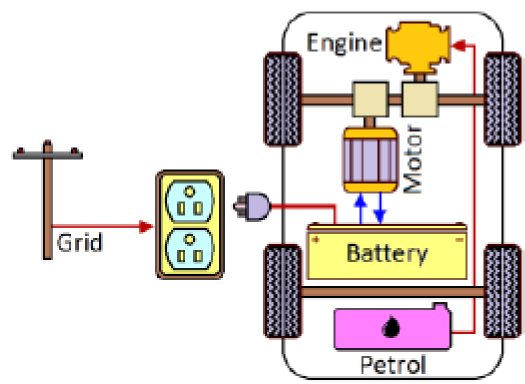
Complex Hybrid EVs (CHEV)

The complex hybrids are similar to series-parallel hybrids but use more complex designs depending on the number of motors/generators and their configuration. Motor power flow in these designs is bi-directional as compared to unidirectional flow in the series-parallel hybrid.

Example: Ford Escape.

Plug-in Hybrid Electric Vehicles (PHEV)

The Plug-in hybrid EVs are full-hybrids which use a smaller engine, a larger battery and a larger motor. Batteries of PHEVs can be recharged from any external power source unlike in standard HEVs in which batteries are recharged only by means of the engine driven generator or regenerative braking. This feature of PHEV has the advantage of drawing electricity from any resource such as grid power including household supply, autonomous systems or even renewable energy. PHEVs have a shorter all-electric driving range per recharge as against battery EVs, but have a larger all-electric range as compared to standard HEVs because the engine-generator drive can assist the system when the batteries are depleted. Also, owing to the large electric motor, PHEVs have higher regenerative braking capability compared to traditional HEVs.



Plug-in Hybrid EV

Examples: Chevy Volt, Toyota Prius, Ford CMax Energi.

Benefits of PHEV: Better fuel efficiency than regular HEV, long driving range than EVs, potential for distributed energy storage, low running cost compared to petrol, and environmentally friendly.
Major disadvantages: High cost and non-availability of fast charging stations.

Social & Environmental importance of hybrid & electric vehicles:

***Social importance*:**

- Electric Vehicle (EV) technology is gaining ground and popularity rapidly. With depletion of oil reserves and a world characterized by smog, noise and all kinds of pollutants, governments and communities are awakening to the several benefits of EV technology.

- Zero emission vehicles are almost noiseless and can be charged at home or work, saving commuters endless queues at petrol stations. Charging at night when consumption is low, allows for efficient use of electricity.
- EVs are easier to service and maintain due to the absence of spark plugs, clutch and gears. Ideal for "stop - start" city driving conditions, EVs are extremely reliable and easy to drive.
- With the innumerable advantages of EVs, companies in developed countries have spent huge amounts to develop electric cars that can travel longer distances, providing high levels of comfort.
- In spite of this technology being available now, the cost of electric vehicles to suit driving requirements in these developed countries is prohibitively high.

***Environmental importance*:** There are two environmental impacts. Those are (a) Air pollution (AP) and (b) Greenhouse gas (GHG) emissions.

The main Greenhouse gases were CO_2, CH_4, N_2O, and SF_6 (sulfur hexafluoride), which have Greenhouse gas impact weighting coefficients relative to CO_2 of 1, 21, 310, and 24,900, respectively. For AP, the airborne pollutants CO, NO_x, SO_x, and VOCs are assigned the following weighting coefficients: 0.017, 1, 1.3, and 0.64, respectively.

The vehicle production stage contributes to the total life cycle environmental impact through the pollution associated with (a) The extraction and processing of material resources, (b) Manufacturing and (c) The vehicle disposal stage.

Additional sources of Greenhouse gas and Air pollution emissions were associated with the fuel production and utilization stages. The environmental impacts of these stages have been evaluated in numerous life cycle assessments of fuel cycles.

Important questions:

1(a). Briefly explain the history of electric vehicles.

(b). Briefly explain the history of hybrid electric vehicles.

2. Explain about EVs with its classification with neat diagrams.

3. Explain about HEVs with its classification with neat diagrams.

4 Explain social & environmental importance of hybrid & electric vehicles