# Unit - 1

# Introduction to Hybrid Electrical Vehicles

## History of electric vehicle

In 1900, steam technology was advanced. The advantages of steam-powered cars Included high performance in terms of power and speed. However, the disadvantages of Steam-powered cars included poor fuel economy and the need to “fire up the boiler”Before driving. Feed water was a necessary input for steam engine, therefore could not Tolerate the loss of fresh water. Later, Steam condensers were applied to the steam car to solve the feed water problem. However, by that time Gasoline cars had won the Marketing battle.

Gasoline cars of 1900 were noisy, dirty, smelly, cantankerous, and unreliable. In comparison, electric cars were comfortable, quiet, clean, and fashionable. Ease of control was also a desirable feature. Lead acid batteries were used in 1900 and are still used in modern cars. Hence lead acid batteries have a long history (since 1881) of use as a viable energy storage device. Golden age of Electrical vehicle marked from 1890 to 1924 with peak production of electric vehicles in 1912. However, the range was limited by energy storage in the battery. After every trip, the battery required recharging. At the 1924automobile show, no electric cars were on display. This announced the end of the Golden Age of electric-powered cars.

The range of a gasoline car was far superior to that of either a steam or an electric car and dominated the automobile market from 1924 to 1960. The gasoline car had one dominant feature; it used gasoline as a fuel. The modern period starts with the oil embargoes and the gasoline shortages during the 1970s which created long lines at gas stations. Engineers recognized that the good features of the gasoline engine could be combined with those of the electric motor to produce a superior car. A marriage of the two yields the hybrid automobile.

- 1769
  The first steam-powered vehicle was designed by Nicolas-Joseph Cug not and constructed by M. Brezin that could attain speeds of up to 6 km/hour. These early steam-poweredvehicles were so heavy that they were only practical on a perfectly flat surface as stron gas iron.
- 1807
  The next step towards the development of the car was the invention of the internal combustion engine. Francois Isaac de Rivaz designed the first internal combustion engine in, using a mixture of hydrogen and oxygen to generate energy.

- 1825
  British inventor Golds worthy Gurney built a steam car that successfully completed an 85mile round-trip journey in ten hours’ time.

- ➢ 1839
  Robert Anderson of Aberdeen, Scotland built the first electric vehicle.

- ➢ 1860
  In, Jean Joseph Etienne Lenoir, a Frenchman, built the first successful two-stroke gas driven engine.

- ➢ 1886
  Historical records indicate that an electric-powered taxicab, using a battery with 28 cells and a small electric motor, was introduced in England.

- ➢ 1888
  Immisch& Company built a four-passenger carriage, powered by a one-horsepowermotor and 24-cell battery, for the Sultan of the Ottoman Empire. In the same year,Magnus Volk in Brighton, England made a three-wheeled electric car. 1890 – 1910.

## History of Hybrid vehicle

Invention Of hybrid vehicle

- ➢ 1890
  Jacob Lohner, a coach builder in Vienna, Austria, foresaw the need for an electric vehicle that would be less noisy than the new gas-powered cars. He commissioned a design for an electric vehicle from Austro-Hungarian engineer Ferdinand Porsche, who had recently graduated from the Vienna Technical College. Porsche's first version of the electric car used a pair of electric motors mounted in the front wheel hubs of a conventional car. The car could travel up to 38 miles. To extend the vehicle's range, Porsche added a gasoline engine that could recharge the batteries, thus giving birth to the first hybrid, the Lohner-Porsche Elektromobil.

- ➢ Early Hybrid Vehicles

- ➢ 1900
  Porsche showed his hybrid car at the Paris Exposition of 1900. A gasoline engine was used to power a generator which, in turn, drove a small series of motors. The electric engine was used to give the car a little bit of extra power. This method of series hybrid engine is still in use today, although obviously with further scope of performance improvement and greater fuel savings.

- ➢ 1915
  Woods Motor Vehicle manufacturers created the Dual Power hybrid vehicle, second hybrid car in market. Rather than combining the two power sources to give a single output of power, the Dual Power used an electric battery motor to power the engine at low speeds (below 25km/h) and used the gasoline engine to carry the vehicle from these low speeds up to its 55km/h maximum speed. While Porsche had invented the series hybrid, Woods invented the parallel hybrid.

- 1918

  The Woods Dual Power was the first hybrid to go into mass production. In all, some 600models were built by. However, the evolution of the internal combustion engine left electric power a marginal technology

- 1960

  Victor Wouk worked in helping create numerous hybrid designs earned him the nickname of the "Godfather of the Hybrid". In 1976 he even converted a Buick Skylark from gasoline to hybrid.

- 1978

  Modern hybrid cars rely on the regenerative braking system. When a standard combustion engine car brakes, a lot of power is lost because it dissipates into the atmosphere as heat. Regenerative braking means that the electric motor is used for slowing the car and it essentially collects this power and uses it to help recharge the electric batteries within the car. This development alone is believed to have progressed hybrid vehicle manufacture significantly. The Regenerative Braking System, was first designed and developed in 1978 by David Arthurs. Using standard car components he converted an Opel GT to offer 75 miles to the gallon and many home conversions are done using the plans for this system that are still widely available on the Internet.

## Importance of hybrid and electric vehicle related to environmental and social

As modern culture and technology continue to develop, the growing presence of global warming and irreversible climate change draws increasing amounts of concern from the world's population. It has only been recently, when modern society has actually taken notice of these changes and decided that something needs to change if the global warming process is to be stopped.

Countries around the world are working to drastically reduce $CO_2$ emissions as well as other harmful environmental pollutants. Among the most notable producers of these pollutants are automobiles, which are almost exclusively powered by internal combustion engines and spew out unhealthy emissions.

According to various reports, cars and trucks are responsible for almost 25% of $CO_2$ emission and other major transportation methods account for another 12%. With immense quantities of cars on the road today, pure combustion engines are quickly becoming a target of global warming blame. One potential alternative to the world's dependence on standard combustion engine vehicles are hybrid cars. Cost-effectiveness is also an important factor contributing to the development of an environment friendly transportation sector.

- Hybrid Vehicle

  A hybrid vehicle combines any type of two power (energy) sources. Possible combinations include diesel/electric, gasoline/fly wheel, and fuel cell (FC)/battery. Typically, one energy source is storage, and the other is conversion of a fuel to energy. In the majority of modern hybrids, cars are powered by a combination of traditional gasoline power and the addition of an electric motor.

However, hybrid still use the petroleum based engine while driving so they are not completely clean, just cleaner than petroleum only cars. This enables hybrid cars to have the potential to segue into new technologies that rely strictly on alternate fuel sources.

The design of such vehicles requires, among other developments, improvements in power train systems, fuel processing, and power conversion technologies. Opportunities for utilizing various fuels for vehicle propulsion, with an emphasis on synthetic fuels (e.g., hydrogen, biodiesel, bioethanol, dimethylether, ammonia, etc.) as well as electricity via electrical batteries, have been analyzed over the last decade.

- Economical Analysis

A number of key economic parameters that characterize vehicles were:

A. Vehicle price,

B. Fuel cost, and

C. Driving range

This case neglected maintenance costs; however, for the hybrid and electric vehicles, the cost of battery replacement during the lifetime was accounted for. The driving range determines the frequency (number and separation distance) of fueling stations for each vehicle type. The total fuel cost and the total number of kilometers driven were related to the vehicle life.

For the Honda FCX the listed initial price for a prototype leased in 2002 was USk$2,000, which is estimated to drop below USk$100 in regular production. Currently, a Honda FCX can be leased for 3 years with a total price of USk$21.6. In order to render the comparative study reasonable, the initial price of the hydrogen fuel cell vehicle is assumed here to be USk$100. For electric vehicle, the specific cost was estimated to US$569/kWh with nickel metal hydride (NiMeH)batteries which are typically used in hybrid and electric cars.

Historical prices of typical fuels were used to calculate annual average price.

- Environmental Analysis

Analysis for the first five options was based on published data from manufacturers. The results for the sixth case, i.e. the ammonia-fueled vehicle, were calculated from data published by For don the performance of its hydrogen-fueled Ford Focus vehicle. Two environmental impact elements were accounted for in the:

a) Air pollution (AP) and b) Greenhouse gas (GHG) emissions.

The main GHGs were $CO_2$, $CH_4$, $N_2O$, and $SF_6$ (sulfur hexafluoride), which have GHG impact weighting coefficients relative to $CO_2$ of 1, 21, 310, and 24,900, respectively. For AP, the airborne pollutants CO, NOx, SOx, 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 GHG and AP 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. Regarding electricity production for the electric car case, three case scenarios were considered here:

AP emissions were calculated assuming that GHG emissions for plant manufacturing correspond entirely to natural gas combustion. GHG and AP emissions embedded in manufacturing a natural gas power generation plant were negligible compared to the direct emissions during its utilization. Taking those factors into account, GHG and AP emissions for the three scenarios of electricity generation were presented in Table 2.

Hydrogen charging of fuel tanks on vehicles requires compression. Therefore, presented case considered the energy for hydrogen compression to be provided by electricity.

GHG and AP emissions were reported for hydrogen vehicles for the three electricity-generation scenarios considered (see table 3), accounting for the environmental effects of hydrogen compression.

The environmental impact of the fuel utilization stage, as well as the overall life cycle is presented in Table 4. The H2-ICE vehicle results were based on the assumption that the only GHG emissions during the utilization stage were associated with the compression work, needed to fill the fuel tank of the vehicle. The GHG effect of water vapor emissions was neglected in this analysis due its little value,. For the ammonia fuel vehicle, a very small amount of pump work was needed therefore, ammonia fuel was considered to emit no GHGs during fuel utilization.

## Historical development (root) of Automobiles

The first working steam-powered vehicle was designed — and quite possibly built — by Ferdinand Verbiest, a Flemish member of a Jesuit mission in China around 1672. It was a 65-cm-long scale-model toy for the Chinese Emperor that was unable to carry a driver or a passenger. It is not known with certainty if Verbiest's model was successfully built or run.

Nicolas-Joseph Cugnot is widely credited with building the first full-scale, self-propelled mechanical vehicle or car in about 1769; he created a steam-powered tricycle. He also constructed two steam tractors for the French Army, one of which is preserved in the French National Conservatory of Arts and Crafts. His inventions were, however, handicapped by problems with water supply and maintaining steam pressure. In 1801, Richard Trevithick built and demonstrated his Puffing Devil road locomotive, believed by many to be the first demonstration of a steam-powered road vehicle. It was unable to maintain sufficient steam pressure for long periods and was of little practical use.

The development of external combustion engines is detailed as part of the history of the car but often treated separately from the development of true cars. A variety of steam-powered road vehicles were used during the first part of the 19th century, including steam cars, steam buses, phaetons, and steam rollers. Sentiment against them led to the Locomotive Acts of 1865.

In 1807, Nicéphore Niépce and his brother Claude created what was probably the world's first internal combustion engine (which they called a Pyréolophore), but they chose to install it in a boat on the river Saone in France. Coincidentally, in 1807 the Swiss inventor François Isaac de Rivaz designed his own 'de Rivaz internal combustion engine' and used it to develop the world's first vehicle to be powered by such an engine. The Niépces' Pyréolophore was fuelled by a mixture of Lycopodium powder (dried spores of the Lycopodium plant), finely crushed coal dust and resin that were mixed with oil, whereas de Rivaz used a mixture of hydrogen and oxygen. Neither design was very successful, as was the case with others, such as Samuel Brown, Samuel Morey, and Etienne Lenoir with his hippomobile, who each produced vehicles (usually adapted carriages or carts) powered by internal combustion engines.

In 1879, Benz was granted a patent for his first engine, which had been designed in 1878. Many of his other inventions made the use of the internal combustion engine feasible for powering a vehicle. His first *Motorwagen* was built in 1885 in Mannheim, Germany. He was awarded the patent for its invention as of his application on 29 January 1886 (under the auspices of his major company, Benz & Cie., which was founded in 1883).

Benz began promotion of the vehicle on 3 July 1886, and about 25 Benz vehicles were sold between 1888 and 1893, when his first four-wheeler was introduced along with a model intended for affordability. They also were powered with four-stroke engines of his own design. Emile Roger of France, already producing Benz engines under license, now added the Benz car to his line of products.

Because France was more open to the early cars, initially more were built and sold in France through Roger than Benz sold in Germany. In August 1888 Bertha Benz, the wife of Karl Benz, undertook the first road trip by car, to prove the road-worthiness of her husband's invention.

In 1892, German engineer Rudolf Diesel was granted a patent for a "New Rational Combustion Engine". In 1897, he built the first diesel engine. Steam-, electric-, and gasoline-powered vehicles competed for decades, with gasoline internal

combustion engines achieving dominance in the 1910s. Although various piston less rotary engine designs have attempted to compete with the conventional piston and crankshaft design, only Mazda's version of the Wankel engine has had more than very limited success.
All in all, it is estimated that over 100,000 patents created the modern automobile and motorcycle.

## CONVENTIONAL VEHICLES

See pdf

# UNIT-1

# HYBRID ELECTRIC DRIVE-TRAINS

## Types of HEVs based on this general definition

A hybrid vehicle combines any two power (energy) sources. Possible combinations include diesel/electric, gasoline/fly wheel, and fuel cell (FC)/battery. Typically, one energy source is storage, and the other is conversion of a fuel to energy. The combination of two power sources may support two separate propulsion systems. Thus to be a True hybrid, the vehicle must have at least two modes of propulsion.

A hybrid-electric vehicle indicates that one source of power is provided by an electric motor. The other source of motive power can come from a number of different technologies, but is typically provided by an internal combustion engine designed to run on either gasoline or diesel fuel.

- Based on this general definition, there are many types of HEVs, such as the gasoline ICE and battery
  - diesel ICE and battery
  - battery and FC
  - battery and capacitor
  - battery and flywheel
  - battery and battery hybrids.

- **Parallel Hybrid**
- **Series Hybrid**
- **Electric traction motors**
- **Power-split or series-parallel hybrid**

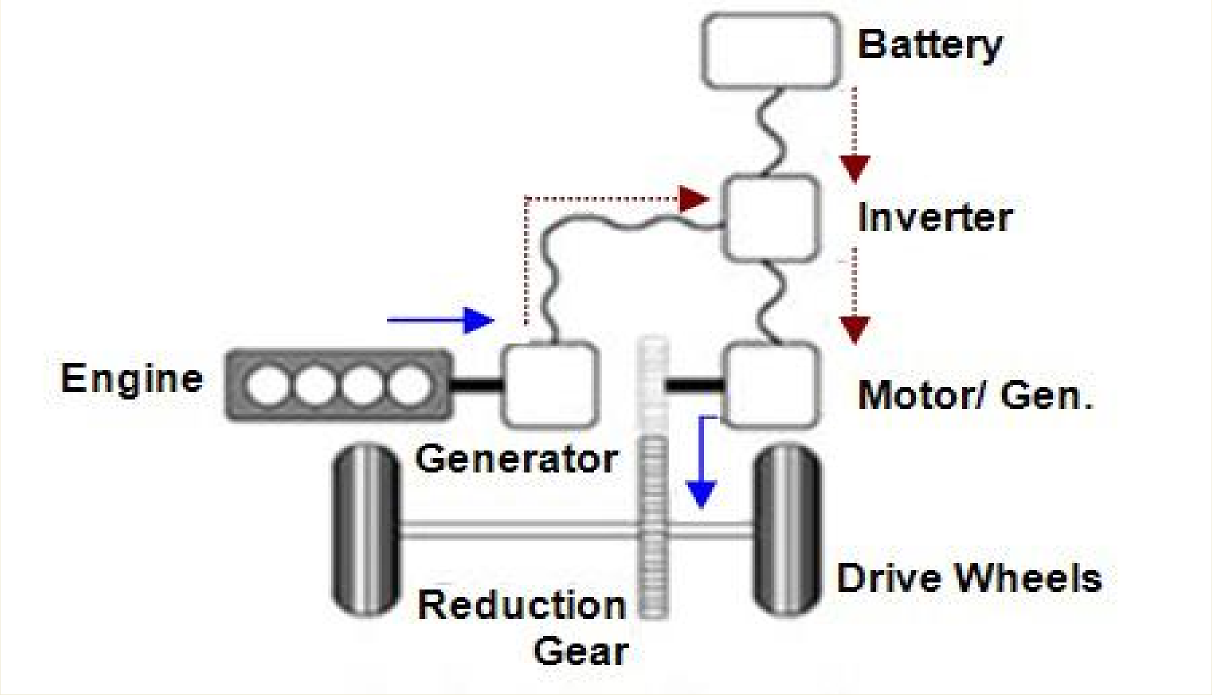
## Introduction to various hybrid drive-train topologies

### SERIES CONFIGURATION HEVS

Series drivetrains are the simplest hybrid configuration. In a series hybrid, the electric motor is the only means of providing power to the wheels. The motor receives electric power from either the battery pack or from a generator run by a gasoline engine. A computer determines how much of the power comes from the battery or the engine/generator. Both the engine/generator and the use of regenerative braking recharge the battery pack.

Series hybrids perform at their best during stop-and-go traffic, where gasoline and diesel engines are inefficient. The vehicle's computer can opt to power the motor with the battery pack only, saving the engine for situations where it's more efficient.

The engine is typically smaller in a series drivetrain because it only has to meet certain power demands; the battery pack is generally more powerful than the one in parallel hybrids in order to provide the remaining power needs. This larger battery and motor, along with the generator, add to the vehicle's cost, making series hybrids more expensive than parallel hybrids.

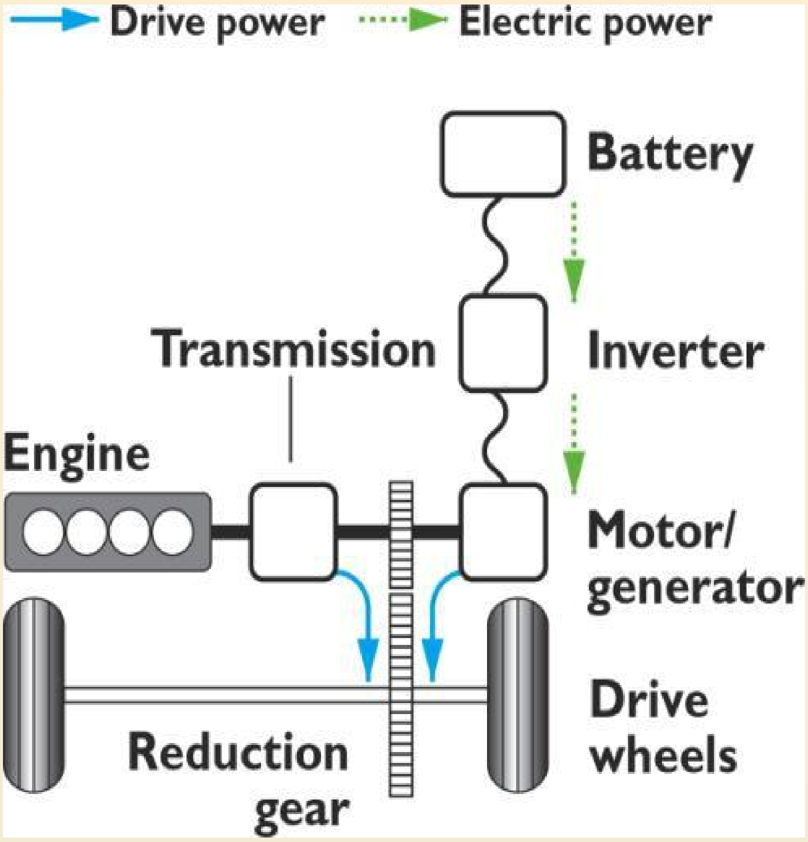



*Series EHV Configuration*

## PARALLEL CONFIGURATION HEVS

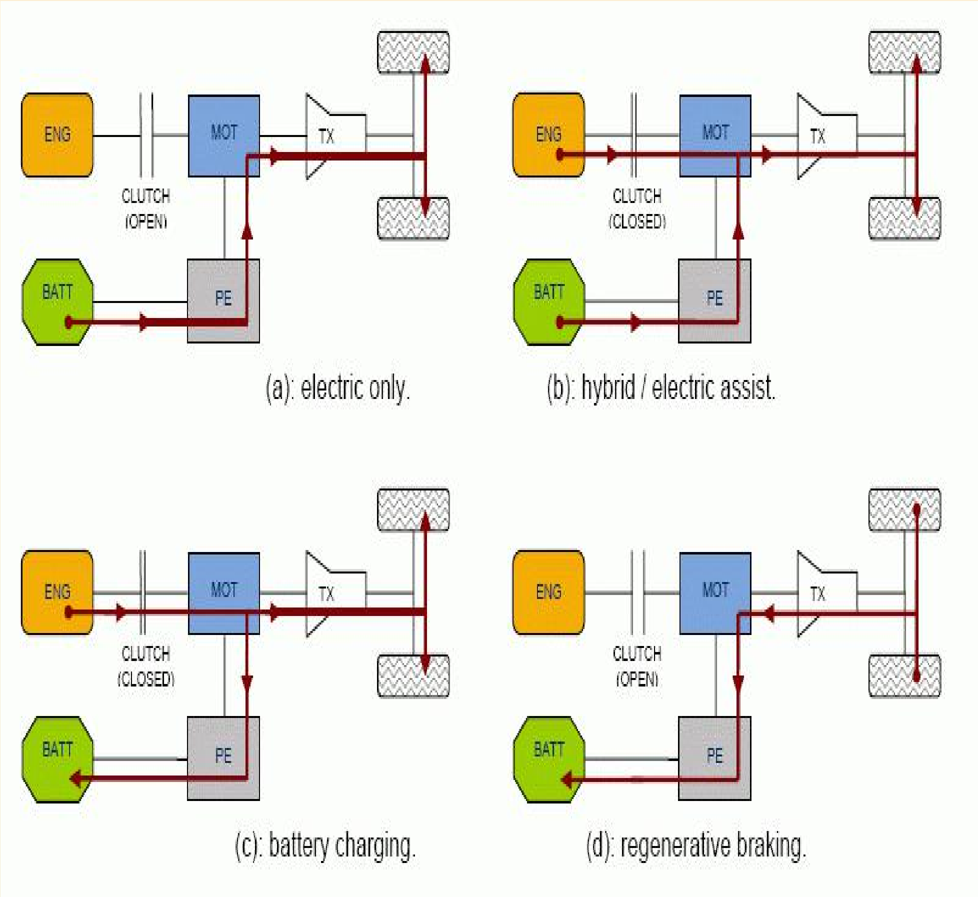
Parallel hybrid systems have both an internal combustion engine (ICE) and an electric motor in parallel connected to a mechanical transmission.
Most designs combine a large electrical generator and a motor into one unit, often located between the combustion engine and the transmission, replacing both the conventional starter motor and the alternator (see figures above).

The battery can be recharged during regenerative breaking, and during cruising (when the ICE power is higher than the required power for propulsion). As there is a fixed mechanical link between the wheels and the motor (no clutch), the battery cannot be charged when the car isn't moving.




*Parallel EHV Configuration*

## ■ Working Diagram




*Working of HEV*

***Some typical modes for a parallel hybrid configuration PE = Power electronics***

***TX = Transmission***

electric power only: Up to speeds of usually 40 km/h, the electric motor works with only the energy of the batteries, which are not recharged by the ICE. This is the usual way of operating around the city, as well as in reverse gear, since during reverse gear the speed islimited.

ICE power only: At speeds superior to 40 km/h, only the heat engine operates. This is thenormal operating way at theroad.

ICE + electric power: if more energy is needed (during acceleration or at high speed), the electric motor starts working in parallel to the heat engine, achieving greater power

ICE + battery charging: if less power is required, excess of energy is used to charge the batteries. Operating the engine at higher torque than necessary, it runs at a higher efficiency.

Regenerative breaking: While braking or decelerating, the electric motor takes profit of the kinetic energy of the he moving vehicle to act as agenerator.

## Series- Parallel configuration HEVs

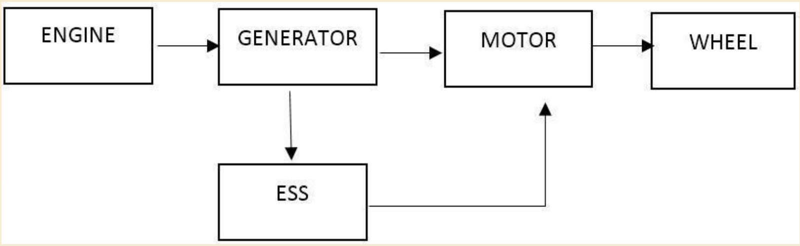
### Construction

Series hybrid is simple configuration, shown in figure below. The ICE used to generate electricity in a generator.

Electric power produced by the generator goes to either the motor or the energy storage systems (ESS). The hybrid power summed at an electrical node, the motor.

The latest replenishment of the hybrid vehicle, several automotive OEMs revealed the chance of development of SHEV.

Some of the most known are the Mitsubishi ESR, Volvo ECC, and BMW 3 Series. The series hybrid configuration have an affinity for high efficiency to engine operation.




*Construction of Series-Parallel EHV*

- **Working**

The regenerative braking assistances from the full size motor. The cost and weight of thevehicles more because of large size of the engine and need of two electric machine.

The series architecture presumed to be more appropriate for vehicles used in city/towns with quickly varying requirements of speed.

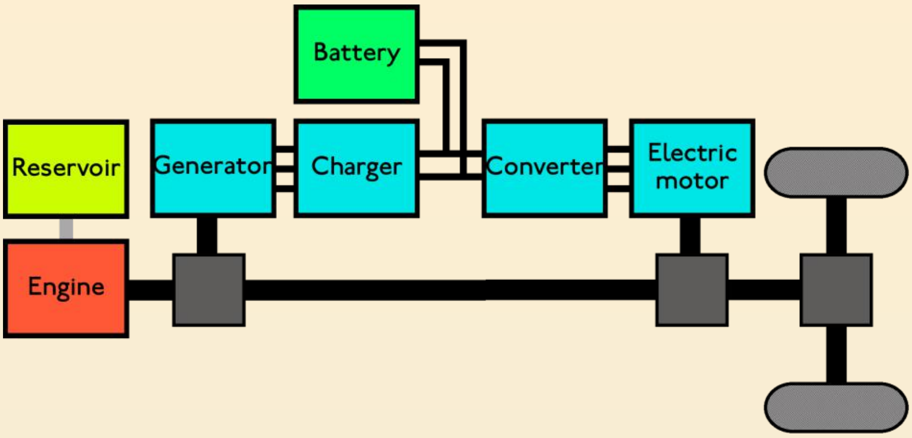
SHEV can also implemented in large vehicles, where the lower efficiency of both ICE and the mechanical transmission make it much convenient for the electricpropulsion.

## Complex configuration HEVs

### Construction

Combined hybrid systems have features of both series and parallel hybrids. There is a double connection between the engine and the drive axle: mechanical and electrical. This split power path allows interconnecting mechanical and electrical power, at some cost in complexity.

Power-split devices are incorporated in the powertrain. The power to the wheels can be either mechanical or electrical or both. This is also the case in parallel hybrids. But the main principle behind the combined system is the decoupling of the power supplied by the engine from the power demanded by the driver.




*Simplified structure of a combined hybrid electric vehicle*

- **Working**

  In a conventional vehicle, a larger engine is used to provide acceleration from standstill than one needed for steady speed cruising. This is because a combustion engine's torque is minimal at lower RPMs, as the engine is its own air pump.

  On the other hand, an electric motor exhibits maximum torque at stall and is well suited to complement the engine's torque deficiency at low RPMs.

  In a combined hybrid, a smaller, less flexible, and highly efficient engine can be used. It is often a variation of the conventional Otto cycle, such as the Miller or Atkinson cycle. This contributes significantly to the higher overall efficiency of the vehicle, with regenerative braking playing a much smaller role.

  At lower speeds, this system operates as a series HEV, while at high speeds, where the series powertrain is less efficient, the engine takes over.

  This system is more expensive than a pure parallel system as it needs an extra generator, a mechanical split power system and more computing power to control the dual system.

## Power flow control in hybrid drive-train topologies

### Power Flow Control in Series Hybrid

### Series Hybrid Electric Drive Trains

A series hybrid drive train is a drive train where two power sources feed a single power plant (electric motor) that propels the vehicle. The most commonly found series hybrid drive train is the series hybrid electric drive train shown in Figure. The unidirectional energy source is a fuel tank and the unidirectional energy converter is an engine coupled to an electric generator.The output of the electric generator is connected to an electric power bus through an electronic converter (rectifier). The bidirectional energy source is an electro chemical battery pack, connected to the bus by means of a power electronics converter (DC/DC converter). The electric power bus is also connected to the controller of the electric traction motor. The traction motor can be controlled either as a motor or generator, or in forward or reverse motion. This drive train may need a battery charger to charge the batteries by a wall plug-in from the power network.

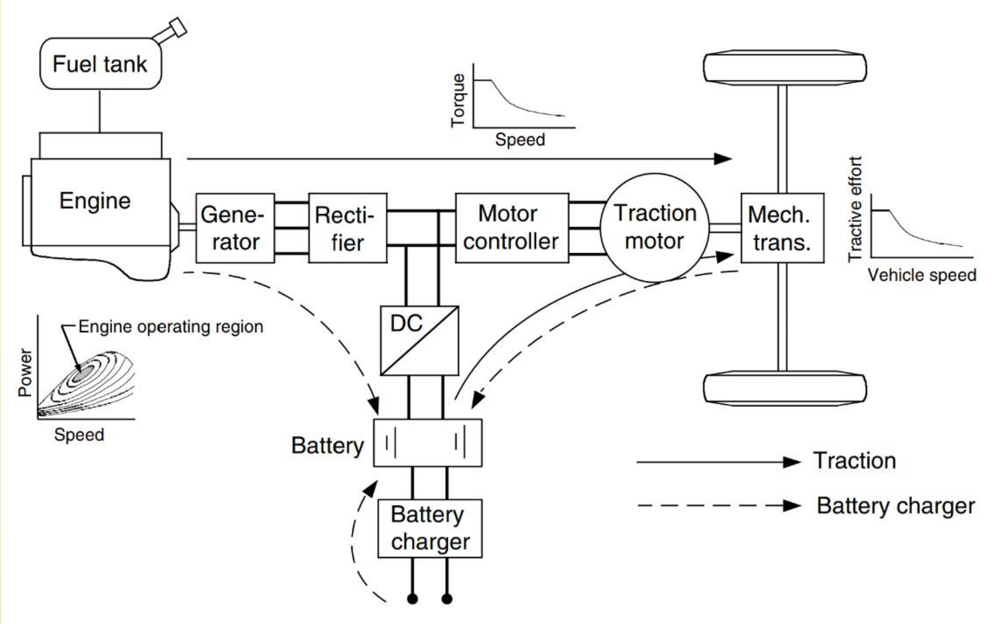



*Fig.Configuration of a series hybrid electric drive train*

- **Series hybrid electric drive trains potentially have the following operation modes:**

Pure electric mode: The engine is turned off and the vehicle is propelled only by the batteries.
Pure engine mode: The vehicle traction power only comes from the engine-generator, while the batteries neither supply nor draw any power from the drive train. The electric machines serve as an electric transmission from the engine to the driven wheels.

Hybrid mode: The traction power is drawn from both the engine generator and the batteries.
Engine traction and battery charging mode: The engine-generator supplies power to charge the batteries and to propel the vehicle.
Regenerative braking mode: The engine-generator is turned off and the traction motor is operated as a generator. The power generated is used to charge the batteries.
Battery charging mode: The traction motor receives no power and the engine-generator charges the batteries.
Hybrid battery charging mode: Both the engine-generator and the traction motor operate as generators to charge the batteries.

➢ **Advantages of a series HEV are:**

Flexibility of location of engine-generator set
Simplicity of drivetrain
Suitability for short trips

➢ **Disadvantages of a series HEV are:**

It needs three propulsion components: ICE, generator, and motor.
The motor must be designed for the maximum sustained power that the vehicle may require, such as when climbing a high grade.
However, the vehicle operates below the maximum power most of the time.
All three drive train components need to be sized for maximum power for long-distance, sustained, high-speed driving.

## Power Flow Control in Parallel Hybrid

**Parallel Hybrid Electric Drive Trains.**

A parallel hybrid drive train is a drive train in which the engine supplies its power mechanically to the wheels like in a conventional ICE-powered vehicle. It is assisted by an electric motor that is mechanically coupled to the transmission.

The powers of the engine and electric motor are coupled together by mechanical coupling, as shown in Figure.
The mechanical combination of the engine and electric motor power leaves room for several different configurations, detailed hereafter.

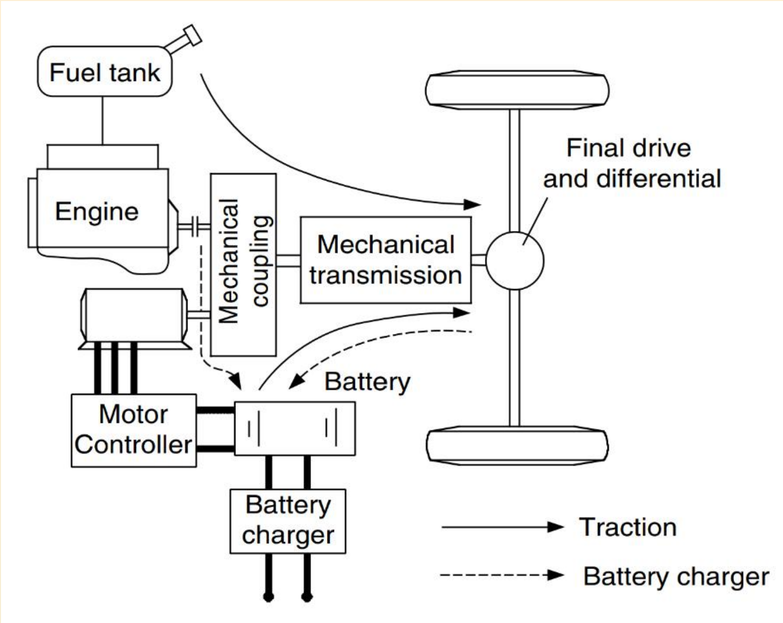



*Fig. Configuration of a parallel hybrid electric drive train*

- **Torque-Coupling Parallel Hybrid Electric Drive Trains**

  The mechanical coupling in Figure may be a torque or speed coupling.
  The torque coupling adds the torques of the engine and the electric motor together or splits the engine torque into two parts: propelling and battery charging.
  Figure conceptually shows a mechanical torque coupling, which has two inputs.
  One is from the engine and one is from the electric motor.
  The mechanical torque coupling outputs to the mechanical transmission.
  If loss is ignored, the output torque and speed can be described by

$T_{out} = k_1 T_{in1} + k_2 T_{in2}$

Where

$k_1$ and $k_2$ are the constants determined by the parameters of torque coupling.
Figure lists some typically used mechanical torque-coupling devices.

There are a variety of configurations in torque coupling hybrid drive trains.
They are classified into two-shaft and one-shaft designs. In each category, the transmission can be placed in different positions and designed with different gears, resulting in different tractive characteristics.
An optimum design will depend mostly on the tractive requirements, engine size and engine characteristics, motor size and motor characteristics, etc.

- **Advantages of a parallel HEV:**

    It needs only two propulsion components: ICE and motor/generator. In parallel HEV, the motor can be used as the generator and vice versa.
    A smaller engine and a smaller motor can be used to get the same performance, until batteries are depleted. For short-trip missions, both can be rated at half the maximum power to provide the total power, assuming that the batteries are never depleted. For long-distance trips, the engine may be rated for the maximum power, while the motor/generator may still be rated to half the maximum power or even smaller.

- **Disadvantages of a parallel HEV:**

    The control complexity increases significantly, because power flow has to be regulated and blended from two parallel sources.
    The power blending from the ICE and the motor necessitates a complex mechanical device.