

An Overview of Hybrid Electrical Vehicles

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Abstract— Electric vehicle drives offer a number of advantages over conventional internal combustion engines, especially in terms of lower local emissions, higher energy efficiency, and decreased dependency upon oil. Yet there are significant barriers to the rapid adoption of electric cars, including the limitations of battery technology, high purchase costs, and the lack of recharging infrastructure. With intelligently controlled charging operations, the energy needs of potential electric vehicle fleets could be covered by existing German power plants without incurring large price fluctuations. Over the long term, electric vehicles could represent a sustainable technology path. In the short to mid-term, however, exceedingly optimistic expectations should be avoided, especially with respect to the reduction of greenhouse gas emissions. Electric vehicles as such will not be able to solve all current problems of transportation policy. Yet they may constitute an important component of a larger roadmap for sustainable transportation.

Keywords— Electric Vehicle, Battery, Fuel Economy, Controller, Power transmission.

I. INTRODUCTION

A hybrid electric vehicle (HEV) has two types of energy storage units, electricity and fuel. Electricity means that a battery (sometimes assisted by ultracaps) is used to store the energy, and that an electromotor (from now on called *motor*) will be used as traction motor. Fuel means that a tank is required, and that an Internal Combustion Engine (ICE, from now on called *engine*) is used to generate mechanical power, or that a fuel cell will be used to convert fuel to electrical energy. In the latter case, traction will be performed by the electromotor only. In the first case, the vehicle will have both an engine and a motor.

- Depending on the drive train structure (how motor and engine are connected), we can distinguish between parallel, series or combined HEVs. This will be explained in paragraph 1.
- Depending on the share of the electromotor to the traction power, we can distinguish between mild or micro hybrid (start-stop systems), power assist hybrid, full hybrid and plug-in hybrid. This will be explained in paragraph 2.
- Depending on the nature of the non-electric energy source, we can distinguish between combustion (ICE), fuel cell, hydraulic or pneumatic power, and human power. In the first case, the ICE is a spark

ignition engines (gasoline) or compression ignition direct injection (diesel) engine. In the first two cases, the energy conversion unit may be powered by gasoline, methanol, compressed natural gas, hydrogen, or other alternative fuels.

A. Motors

Motors are the "work horses" of Hybrid Electric Vehicle drive systems. The electric traction motor drives the wheels of the vehicle. Unlike a traditional vehicle, where the engine must "ramp up" before full torque can be provided, an electric motor provides full torque at low speeds. The motor also has low noise and high efficiency. Other characteristics include excellent "off the line" acceleration, good drive control, good fault tolerance and flexibility in relation to voltage fluctuations. The front-running motor technologies for HEV applications include PMSM (permanent magnet synchronous motor), BLDC (brushless DC motor), SRM (switched reluctance motor) and AC induction motor. A main advantage of an electromotor is the possibility to function as generator. In all HEV systems, mechanical braking energy is regenerated. The max. operational braking torque is less than the maximum traction torque; there is always a mechanical braking system integrated in a car.

B. Battery

The battery pack in a HEV has a much higher voltage than the SIL automotive 12 Volts battery, in order to reduce the currents and the I²R losses.

C. Accessories

Accessories such as power steering and air conditioning are powered by electric motors instead of being attached to the combustion engine. This allows efficiency gains as the accessories can run at a constant speed or can be switched off, regardless of how fast the combustion engine is running. Especially in long haul trucks, electrical power steering saves a lot of energy.

II. TYPES OF DRIVETRAIN STRUCTURE

A. Series hybrid

In a series hybrid system, the combustion engine drives an electric generator (usually a three-phase alternator plus rectifier) instead of directly driving the wheels. The electric

motor is the only means of providing power to the wheels. The generator both charges a battery and powers an electric motor that moves the vehicle. When large amounts of power are required, the motor draws electricity from both the batteries and the generator.

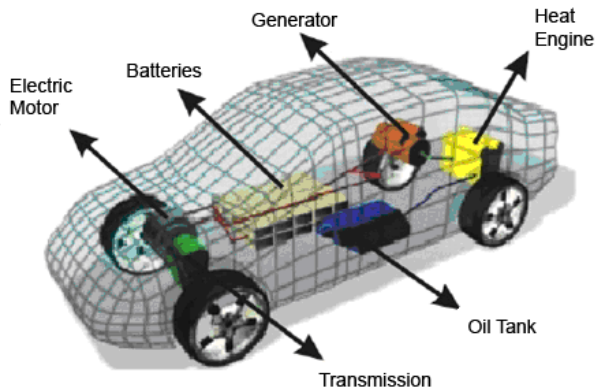


Fig 1 Hybrid Vehicle

Series hybrid configurations already exist a long time: diesel-electric locomotives, hydraulic earth moving machines, diesel-electric power groups, loaders.

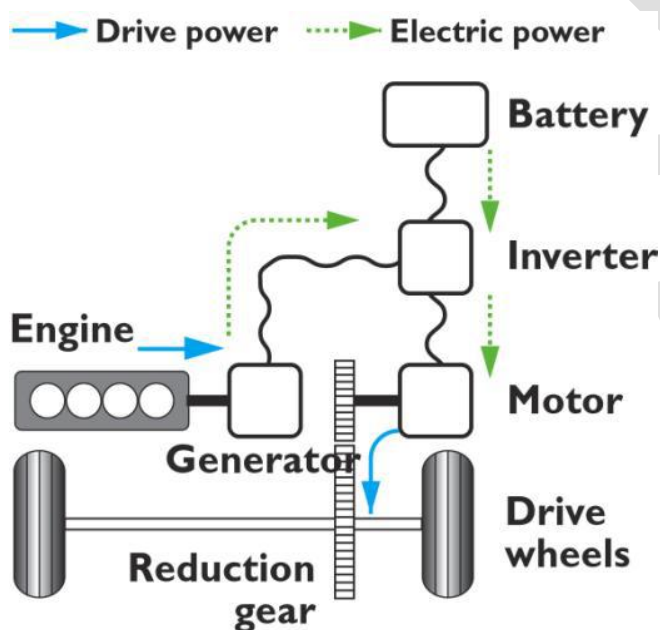


Fig 2 Structure of a series hybrid vehicle

Series hybrids can be assisted by ultracaps (or a flywheel: KERS=Kinetic Energy Recuperation System), which can improve the efficiency by minimizing the losses in the battery. They deliver peak energy during acceleration and take regenerative energy during braking. Therefore, the ultracaps are kept charged at low speed and almost empty at top speed. Deep cycling of the battery is reduced, the stress factor of the battery is lowered.

Some vehicle designs have separate electric motors for each wheel. Motor integration into the wheels has the disadvantage that the unsprung mass increases, decreasing

ride performance. Advantages of individual wheel motors include simplified traction control (no conventional mechanical transmission elements such as gearbox, transmission shafts, differential), all wheel drive, and allowing lower floors, which is useful for buses. Some 8x8 all-wheel drive military vehicles use individual wheel motors.

A fuel cell hybrid electric always has a series configuration: the engine-generator combination is replaced by a fuel cell.

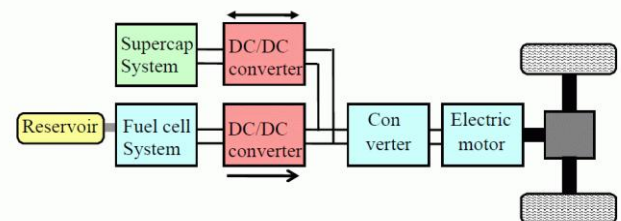


Fig 3 Structure of a fuel cell hybrid electric vehicle

B. Parallel Hybrid

Parallel hybrid systems have both an internal combustion engine (ICE) and an electric motor in parallel connected to a mechanical transmission.

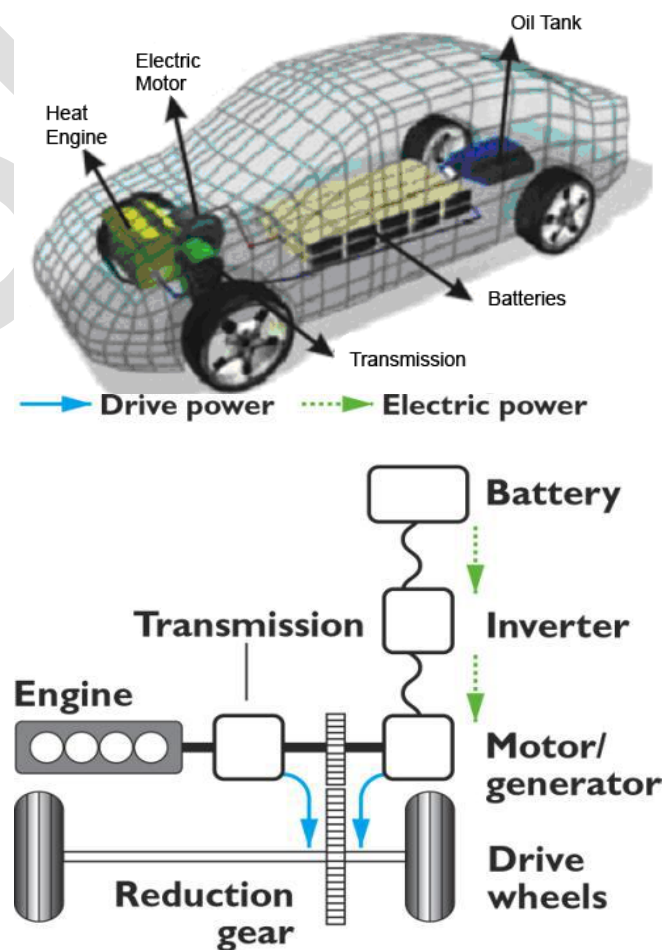


Fig 3 Structure of a parallel hybrid electric vehicle

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 braking, 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.

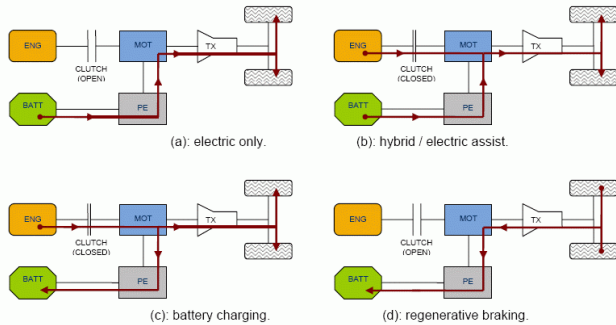


Fig 4 Some typical modes for a parallel hybrid configuration

- (a) 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 is limited.
- (b) ICE power only: At speeds superior to 40 km/h, only the heat engine operates. This is the normal operating way at the road.
- (c) 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
- (d) 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.
- (e) regenerative braking: While braking or decelerating, the electric motor takes profit of the kinetic energy of the he moving vehicle to act as a generator.

Sometimes, an extra generator is used: then the batteries can be recharged when the vehicle is not driving, the ICE operates disconnected from the transmission. But this system gives an increased weight and price to the HEV.

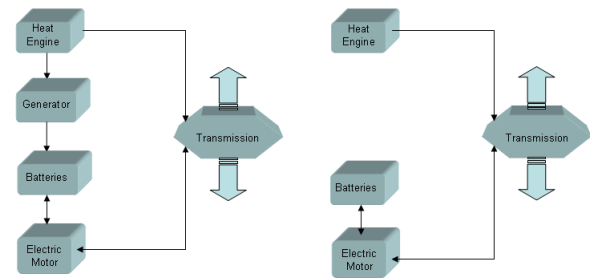


Fig 5 A parallel HEV can have an extra generator for the battery (left) Without generator, the motor will charge the battery (right)

C. Combined Hybrid

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.

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.

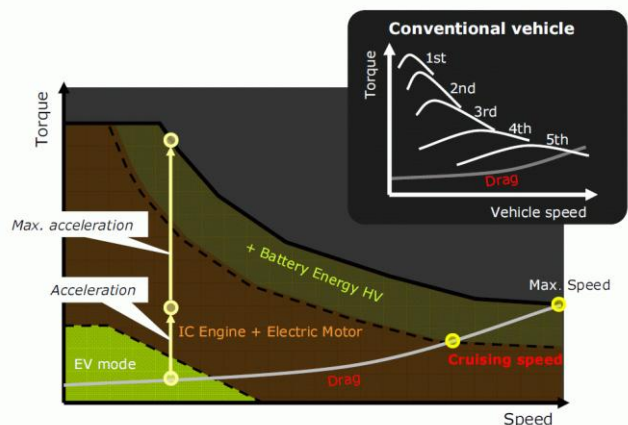


Fig 6 Combined Hybrid Drive Modes

III. TYPES BY DEGREE OF HYBRIDIZATION

Parallel and combined hybrids can be categorized depending upon how balanced the different portions are at providing motive power. In some cases, the combustion engine is the dominant portion; the electric motor turns on only when a boost is needed. Others can run with just the electric system operating.

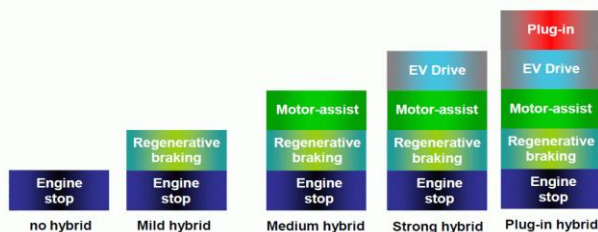


Fig 7 Overview of Hybrid-powertrain concepts

Mild hybrids are essentially conventional vehicles with oversized starter motors, allowing the engine to be turned off whenever the car is coasting, braking, or stopped, yet restart quickly and cleanly. During restart, the larger motor is used to spin up the engine to operating rpm speeds before injecting any fuel. That concept is not unique to hybrids; Subaru pioneered this feature in the early 1980s, and the Volkswagen Lupo 3L is one example of a conventional vehicle that shuts off its engine when at a stop.

As in other hybrid designs, the motor is used for regenerative braking to recapture energy. But there is no motor-assist, and no EV mode at all. Therefore, many people do not consider these to be hybrids, since there is no electric motor to drive the vehicle, and these vehicles do not achieve the fuel economy of real hybrid models.

Some provision must be made for accessories such as air conditioning which are normally driven by the engine. Those accessories can continue to run on electrical power while the engine is off. Furthermore, the lubrication systems of internal combustion engines are inherently least effective immediately after the engine starts; since it is upon startup that the majority of engine wear occurs, the frequent starting and stopping of such systems reduce the lifespan of the engine considerably. Also, start and stop cycles may reduce the engine's ability to operate at its optimum temperature, thus reducing the engine's efficiency.

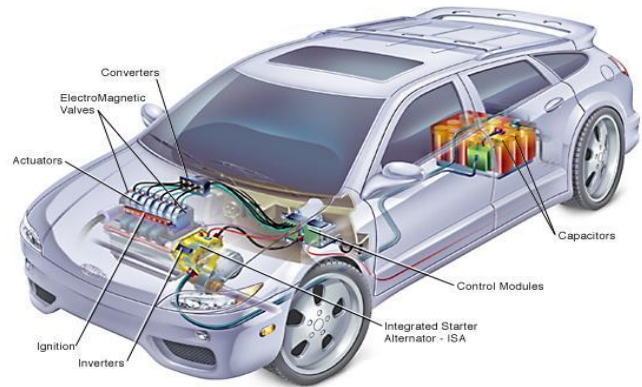


Fig 8 Power train of a mild HEV

The Plug-in-Hybrid Volvo C30 (concept car) is a series HEV. It has a 1,6 liter gasoline/bio-ethanol ICE. A synchronous generator charges the Li-polymer battery (ca. 100 km autonomy) when the battery SoC is lower than 30%. There are four electric wheel-motors.



Fig 9 Plug-in-Hybrid Volvo C30

IV. TYPES BY NATURE OF THE POWER SOURCE

A. Electric-internal combustion engine hybrid

There are many ways to create an electric-internal combustion hybrid. The variety of electric-ICE designs can be differentiated by how the electric and combustion portions of the powertrain connect (series, parallel or combined), at what times each portion is in operation, and what percent of the power is provided by each hybrid component. Many designs shut off the internal combustion engine when it is not needed in order to save energy.

B. Fuel cell hybrid

Fuel cell vehicles have a series hybrid configuration. They are often fitted with a battery or supercapacitor to deliver peak acceleration power and to reduce the size and power constraints on the fuel cell (and thus its cost).

C. Human power and environmental power hybrids

Many land and water vehicles use human power combined with a further power source. Common are parallel hybrids, e.g. a boat being rowed and also having a sail set, or

motorized bicycles. Also some series hybrids exist. Such vehicles can be tribrid vehicles, combining at the same time three power sources e.g. from on-board solar cells, from grid-charged batteries, and from pedals.

D. Pneumatic hybrid

Compressed air can also power a hybrid car with a gasoline compressor to provide the power. Moteur Developpement International in France produces such air cars. A team led by Tsu-Chin Tsao, a UCLA mechanical and aerospace engineering professor, is collaborating with engineers from Ford to get Pneumatic hybrid technology up and running. The system is similar to that of a hybrid-electric vehicle in that braking energy is harnessed and stored to assist the engine as needed during acceleration.

E. Hydraulic hybrid

A hydraulic hybrid vehicle uses hydraulic and mechanical components instead of electrical ones. A variable displacement pump replaces the motor/generator, and a hydraulic accumulator (which stores energy as highly compressed nitrogen gas) replaces the batteries. The hydraulic accumulator, which is essentially a pressure tank, is potentially cheaper and more durable than batteries. Hydraulic hybrid technology was originally developed by Volvo Flygmotor and was used experimentally in buses from the early 1980s and is still an active area.

V. CONCLUSION

Hybrid cars are definitely more environmentally friendly than internal-combustion vehicles. Batteries are being engineered to have a long life. When the hybrid cars become more widespread, battery recycling will become economically possible. Research into other energy sources such as fuel cells and renewable fuels make the future look brighter for hybrid cars.

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