

Electric Powertrains

MIT Electric Vehicle Team, April 2008

An electric vehicle (EV) is a vehicle that is powered, at least in part, by electricity. EV configurations include battery electric vehicles (BEVs) which are powered by 100% electric energy, various hybrid-electric vehicles (HEVs), and plug-in hybrid electric vehicles (PHEVs). This summary presents the differences between these basic EV configurations.

Battery Electric Vehicles

A battery electric vehicle (BEV) is a vehicle that is powered entirely on electric energy, typically a large electric motor and a large battery pack. Based on the type of transmission; the use of a clutch, gearbox, differential, and fixed gearing; and the number of battery packs and motors there are many variations on the BEV design. However, a basic BEV system is shown in Figure 1.

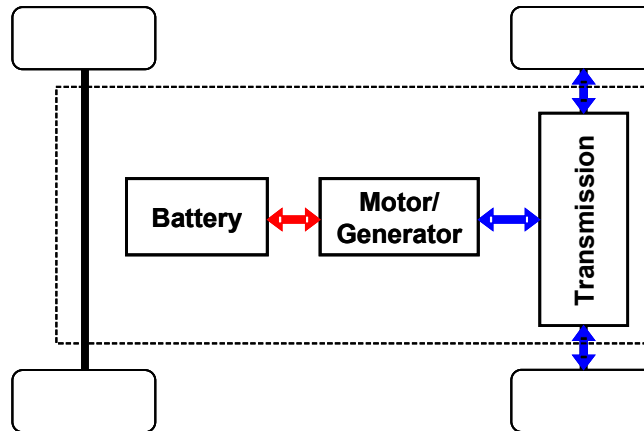


Figure 1: Schematic of a battery electric vehicle (BEV) powertrain

Mild Hybrid Electric Vehicles

Unlike a BEV, a hybrid electric vehicle (HEV) relies on two energy sources, usually an internal combustion engine and an electric battery and motor/generator. A Mild Hybrid is the least electrified type of HEV. A Mild Hybrid is a conventional internal combustion engine (ICE) vehicle with an oversized starter motor that can also be used as a generator, usually called an integrated starter-generator (ISG) or a belted alternator starter (BAS), and an oversized battery that powers and is recharged by the motor. A simple Mild Hybrid system is shown in Figure 2. In a Mild Hybrid, the engine must always be on while the vehicle is moving. However, the motor/generator can be used to enable idle stop in which the engine is turned off while the vehicle is at idle. The motor/generator can be used at high loads to assist the engine and increase vehicle performance. At low loads, it increases load on the engine and recharges the electric battery.

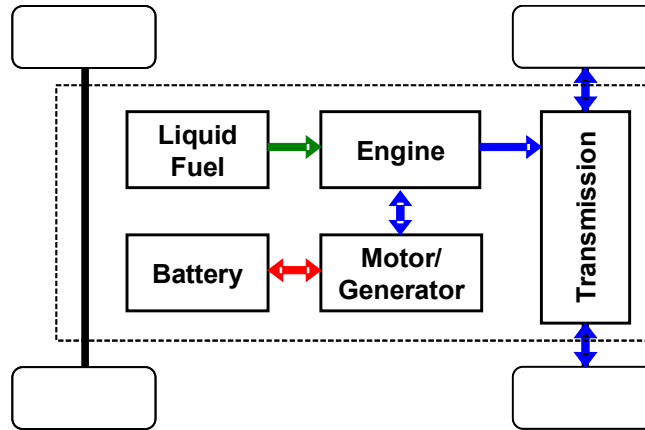


Figure 2: Schematic of a Mild Hybrid powertrain

Series Hybrid Electric Vehicles

In a Series Hybrid there is a single path to power the wheels of the vehicle, but two energy sources. As shown in figure 3, the fuel tank feeds an engine which is coupled to a generator to charge the battery which provides electrical energy to a motor/generator to power the wheels through a transmission although a direct coupling can also be used. The motor/generator is also used to recharge the battery during deceleration and braking.

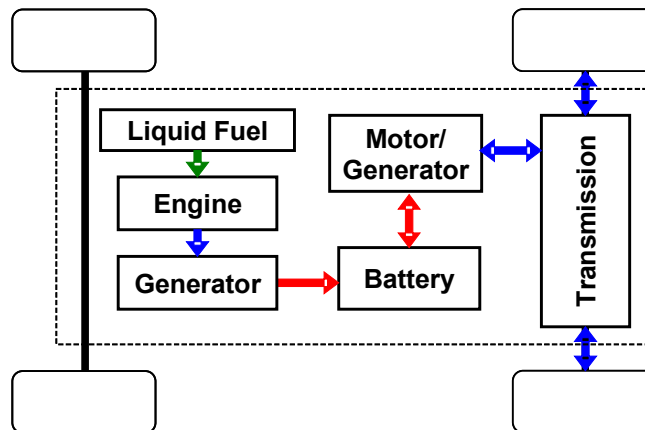


Figure 3: Schematic of a Series Hybrid powertrain

The Series Hybrid can operate in the following seven modes:

- Engine only traction
- Electric only traction
- Hybrid traction
- Engine Traction and Battery Charging
- Battery Charging and No Traction
- Regenerative Braking
- Hybrid Battery Changing

Although most Series Hybrids use an ICE, it is also possible to design a Series Hybrid using a Fuel Cell powered by hydrogen, creating a Fuel Cell Electric Vehicle (FCEV).

Parallel Hybrid Electric Vehicles

In a Parallel Hybrid, there are two parallel paths to power the wheels of the vehicle: an engine path and an electrical path, as shown in figure 4. The transmission couples the motor/generator and the engine, allowing either, or both, to power the wheels. Control of a Parallel Hybrid is much more complex than for a Series Hybrid because of the need to efficiently couple the motor/generator and engine in a way that maintains driveability and performance.

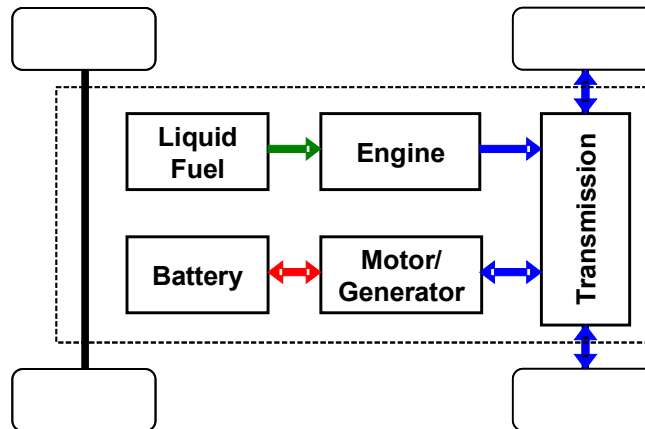


Figure 4: Schematic of a parallel hybrid powertrain

The Parallel Hybrid can operate in the following five modes:

- Engine only traction
- Electric only traction
- Hybrid traction
- Regenerative Braking
- Battery charging from the engine

Series-Parallel Hybrid Electric Vehicles

A Series-Parallel HEV has both Series and Parallel energy paths. As shown in figure 5, a system of motors and/or generators that sometimes includes a gearing or power split device couples allows the engine to recharge the battery. Variations on this configuration can be very complex or simple, depending on the number of motors/generators and how they are used. These configurations can be classified as Complex hybrids (such as the Toyota Prius and Ford Escape Hybrids), Split-Parallel hybrids, or Power-Split hybrids.

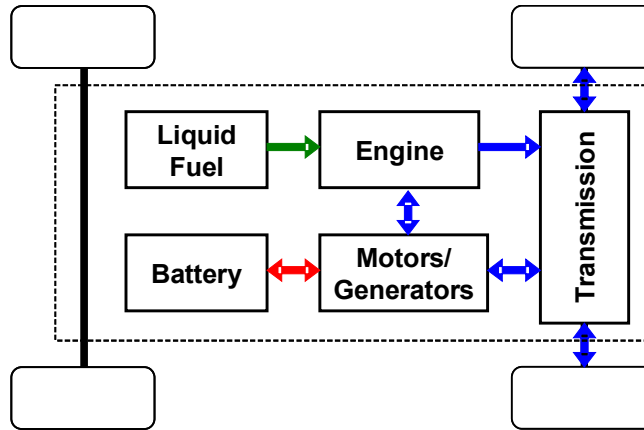


Figure 5: Schematic of a series-parallel hybrid powertrain

Plug-in Hybrid Electric Vehicles

A plug-in hybrid electric vehicle (PHEV) is an HEV that can be plugged-in or recharged from wall electricity. PHEVs are distinguished by much larger battery packs when compared to other HEVs. The size of the battery defines the vehicle's All Electric Range (AER), which is generally in the range of 30 to 50 miles. PHEVs can be of any hybrid configuration. Although no PHEVs are available on the market today, a number of companies have begun to sell conversion kits and services to convert a standard HEV into a PHEV by adding additional battery capacity and modifying the vehicle controller and energy management system.