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Operation of a Hybrid Vehicle Drive-Train System

Likely, many only know hybrid systems have a means of boosting efficiency, but do not know how this is done. This is a short primer explaining the internal workings of a hybrid vehicle.

Overview:

A hybrid vehicle is one in which there are multiple sources of power. This comes directly from the definition of *hybrid*, meaning composite. While in practice there are many ways to achieve this, we will only cover the topic in generalities.

The main reasons why a hybrid vehicle can be more efficient are:

- *Regenerative braking:* recovering some of the energy from the vehicle's momentum rather than losing it all to heat, as in conventional braking systems.
- Running at *peak efficiency:* an internal combustion engine, which conventional vehicles use, has a small range of engine speeds running at the highest efficiency. In some hybrid configurations the engine is allowed to run at this best speed at all times. A conventional vehicle does not have this option.
- *On-demand operation:* the engine management computer in many hybrid vehicles can shut off the conventional engine when it is not needed, and thus save fuel. Times when the engine shuts off may include: at idle in stop and go traffic, when coasting, during braking, or any other time that the extra power is not needed. The conventional engine is only run when actually necessary.

Parts of the System:

There are several options for each of the major components in a hybrid drive system. The more common ones will be discussed here. Keep in mind that it is not an exhaustive list of the possibilities. Although not represented in *Figure 1*, there are also four wheel drive hybrid vehicles. A couple novel options that are available will be discussed, but not all possible permutations.

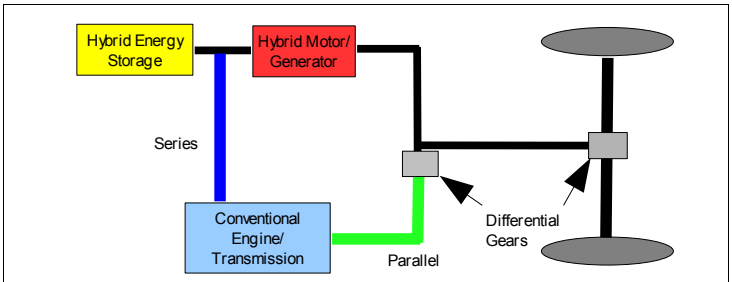

Figure 1: Hybrid Drive Systems

Conventional Engine/Transmission:

The conventional engine can be a basic automotive engine, whether gasoline, diesel, natural gas, or even more esoteric fuels, including a hydrogen fuel cell. See the section *Series System* for an explanation of it's inclusion here. Each of these engines also need a storage tank for its respective fuel source, of course, but for simplicity on the drawing they are implied. The engine is connected to a generator, and in a parallel system to a transmission. The transmission is then mechanically linked to the drive wheels via gears and shafts, as in a basic, non-hybrid vehicle.

Hybrid Energy Storage:

This is the “battery” for storing excess energy to be used later. It can be a literal battery, an ultra-capacitor, a super high-speed flywheel, or a liquid pressure reservoir.

Hybrid Motor/Generator:

The hybrid motor is directly connected to one or more wheels, and creates the motive force. In regenerative braking it also acts as a generator to recover some of the energy from the vehicle's momentum. This can be an electric motor or hydraulic pump.

Vehicle Management Computer:

Similar to conventional vehicles built in recent years, a hybrid vehicle needs a computer to manage the operation of the vehicle. In a hybrid system far more needs to be done by the computer. It needs to govern when to run the conventional engine and when to use the hybrid motor, as well as how much power to supply to the hybrid motor or draw off it. The computer also needs to decide when conventional brakes are required, as in an emergency situation, when regenerative braking might not suffice.

The Two Hybrid Drive Arrangement Possibilities:

The two main options in a hybrid system are *series* and *parallel,* referring to how power travels from the hybrid motor or conventional engine to the drive wheels. In series there is only one path for power. First from the conventional engine, then through a generator and the hybrid motor and then to the wheels. In parallel there are two paths, one from the conventional engine and one from the hybrid motor, although they are often combined by a differential gear assembly before they reach the wheels. In both descriptions below, the hybrid vehicle can be either electric or hydraulic. It is possible for a vehicle to use hydraulic pressure instead of electric volts to transmit and store power. In both cases the theory of operation is the same, it just requires hydraulic pumps and hoses to replace the electric motors and wires.

Series System:

See *Figure 2* for a visual of the hybrid power configuration. In looking at the different power paths, notice that each color line has only *one* source, though they may go to multiple destinations. In this style of hybrid drive there is no mechanical connection between the conventional engine and the wheels. The engine has an electrical generator connected to it, and only creates electrical power. This power is then put into the power bus. Depending on demand the power will go into either the hybrid energy storage, or into the hybrid motor, or both. When demand is low and the energy storage is near full capacity, the engine will shut off to conserve fuel. During these times the hybrid motor can run for short periods purely off stored energy.

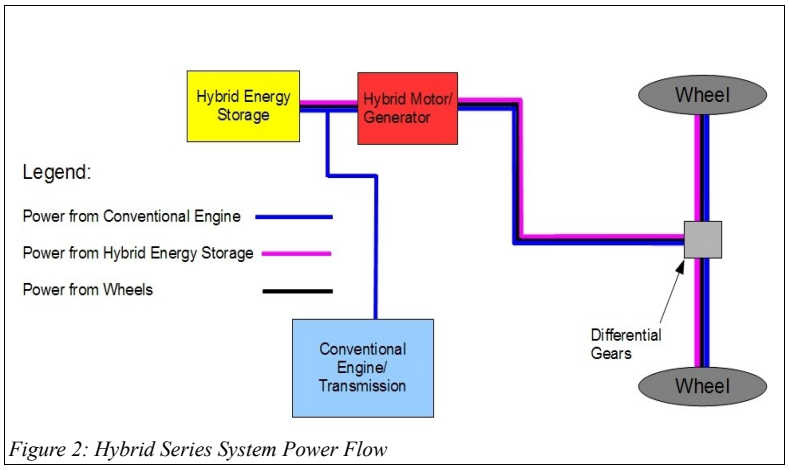

Figure 2: Hybrid Series System Power Flow

A fuel cell also falls into this category, as mentioned earlier. While the fuel cell is not a conventional engine, it does operate in the same way in a vehicle. The fuel cell supplies purely electrical energy, which is then supplied to the system in the same manner as if it was from a conventional engine. Other components in the system are the same as for a hybrid vehicle, for all of the same reasons.

Parallel System:

See *Figure 3* to visualize this system. As with the Series System, each color line only has one source. This system has a direct connection between the conventional engine and at least one of the drive wheels. This requires a conventional style transmission to change gears and allow the engine to operate at all vehicle speeds. If the hybrid motor is connected to the same drive wheels as the engine, then a differential gearing is required between the two to connect them and allow for various power configurations. The differential allows for one or both of the conventional engine and hybrid motor to be supplying power to the wheels. It also allows the hybrid motor to draw power from either the engine or wheels to fill the energy storage.

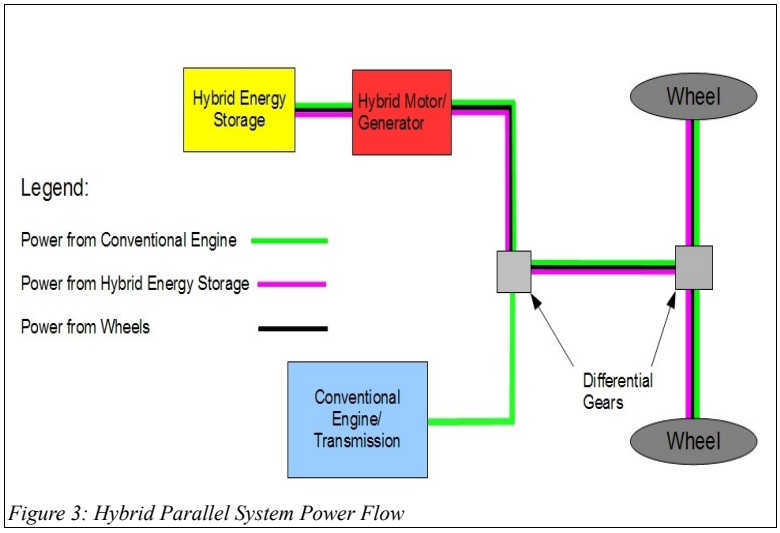

Figure 3: Hybrid Parallel System Power Flow

Additionally, there is the option of connecting the conventional engine to one set of drive wheels, and the hybrid motor to the other set, thus giving effective four wheel drive. Although with this set up there is usually not an option to shut off the conventional engine when the vehicle is in motion, which slightly decreases the fuel efficiency.