2.2 POWER FLOW CONTROL IN HYBRID DRIVE-TRAIN TOPOLOGIES

1. 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 isan 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.

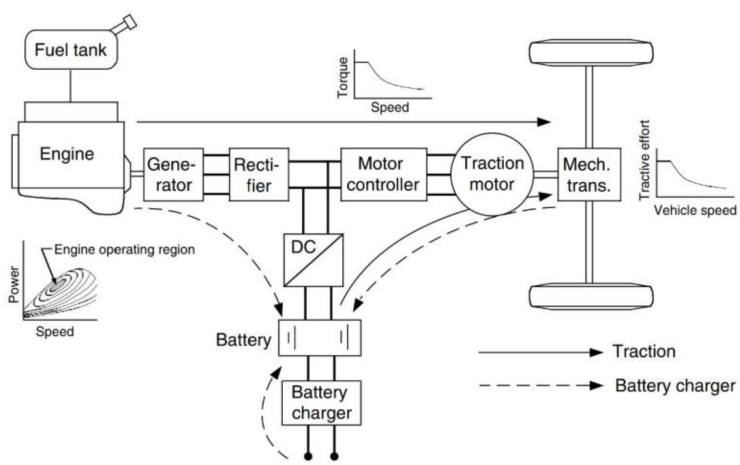

Fig.Configuration of a series hybrid electric drive train

Series hybrid electric drive trains potentially have the following operationmodes:

- Pure electric mode: The engine is turned off and the vehicle is propelled only by thebatteries.
- 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 thedriven 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 tocharge 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:

1. Flexibility of location of engine-generator set
2. Simplicity of drivetrain
3. Suitability for short trips

Disadvantages of a series HEV are:

1. It needs three propulsion components: ICE, generator, and motor.
2. The motor must be designed for the maximum sustained power that the vehicle mayrequire, 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.

2.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 assistedby an electric motor that is mechanically coupled to the transmission.

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

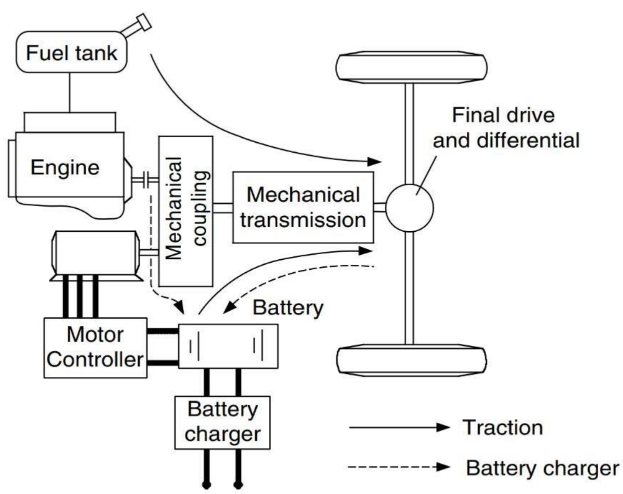

Fig. Configuration of a parallel hybrid electric drive train

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

$$Tout = k1Tin1 + k2Tin2$$

Where *k1*and *k2* 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 parallelHEV, 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 thatthe 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 tohalf the maximum power or even smaller.

Disadvantages of a parallel HEV:

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