

## Research on New Electric Hybrid Powertrain with Two Speed Ratios

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**Abstract.** In order to provide a new power train for electric hybrid vehicles that is simple in structure and lower in cost with higher fuel efficiency. A new power train for electric hybrid vehicle was designed with only one motor, one engine and a two speed ratio gear box. It has six different operation modes and can meet the vehicle driving requirements, and can provide pure electric drive, independent engine drive and hybrid drive with two speed ratios.

### Introduction

There are three main type of powertrain currently used in hybrid electric vehicles, which are series type, parallel type, and series/parallel combined type. In the series system vehicles, the engine drives the generator to supply electricity for electric motor, then the motor drives the vehicle with twice energy conversion, firstly energy transformed from the chemical to the electric, then from the electric to the mechanical. The serial system is easy to realize engine optimized control but with more energy loss. The parallel system can be thought as one set of electric drive system added to the conventional engine drive system, which can provide assistant power in vehicle acceleration and upslope conditions. Its main drawback is that the engine cannot be operated in optimal area with higher fuel efficiency because of mechanical connection between the engine and drive wheels. In parallel/series combined hybrid power train, the engine power is transmitted in two routes, one is to drive generator to charge power battery or drive the motor, and the other is transmitted to drive vehicle directly, the electricity power for the motor is from the power battery or from the generator which depends on real operation condition of SOC. The combined hybrid electric power train has better performance than the parallel and series. But most of the serial/parallel power trains adopt two ore more sets of planetary gear and two electric motors as shown in Figure 1 and 2, which make the assembly structure become more complicated and more difficult to control in addition to higher cost and bigger size[1,2].

In order to reduce the complicity and cost of parallel/series hybrid power trains. Many ideas have been presented in references [3-9]. Especially in reference [10], a 3 speed gear box used for range extender transmission was discussed in the range extending electric vehicles.

In order to reduce the complicity and cost, a new power train was introduced in this paper which is more practical from the viewpoint of authors. And the new power train is designed for general hybrid electric vehicles which can provide six different operation modes. It adopts a two speed gear box, two automatic clutches, one electric motor, and the rotor shaft of the electric motor is directly connected to the input shaft of the two speed gear box without any other speed-reduced gears. The main idea for this new power train is to get higher fuel efficiency with lower cost, simple structure, and smaller power train size.

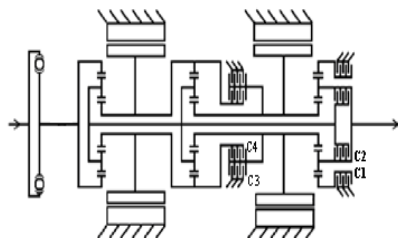


Figure 1. Two mode hybrid electric powertrain of GM.

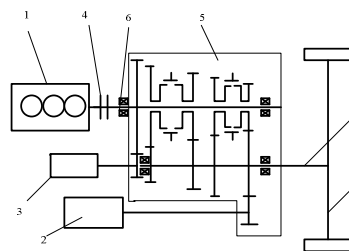


Figure 2. Sketch of powertrain with 2 motors and 4gears.

## Composition of New Power Train

This new power train is mainly composed of one engine, two clutches, one two speed ratio gear box and one electric motor, as shown in Figure 3. This structure is simple with easy manufacture and control strategy. Application of only one electric motor can reduce the cost and size of powertrain, and the motor mainly provides power for lower vehicle speed. The engine power is for higher vehicle speed application most of time. With lower cost, the two speed ratios can provide a better efficiency for engine and motor operation.

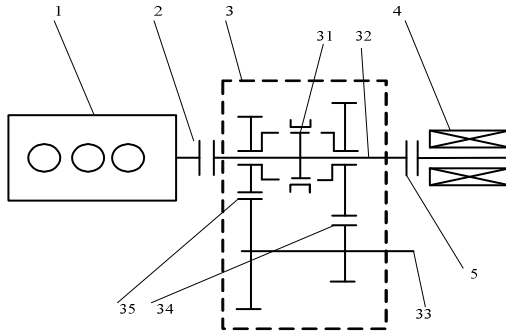


Figure 3. Sketch of power train with two speed ratio.

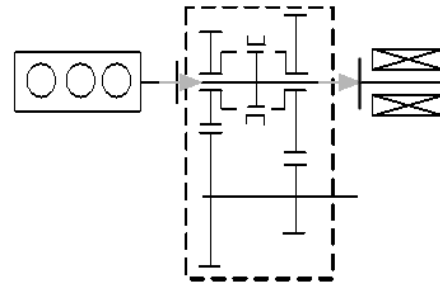


Figure 4. Power battery charge mode.

1 engine, 2 first clutch, 3 gear box, 4 motor, 5 second clutch, 31 synchronizer, 32 input shaft, 33 output shaft, 34 first gear, 35, second gear.

In this new powertrain, there are two automatic clutches, one located between engine and gear box to break the engine power output, the other one is for electric motor power break between the gear box and motor.

And the gear box is composed of two sets of gears, two shafts and one set of synchronizer system, which can provide two speed ratios. About these two speed ratios, one is more than 1.0 and the other is less than 1.0. These two speed ratios are for higher engine speed conditions. The automatic synchronizer system has three states, which are first gear connection, second gear connection and neutral position. With this two speed gear box, the powertrain can select favorable gear by the control strategy to make the engine and motor operated at high efficiency area.

There are also several drawbacks for this power train: 1) the clutch disengagement and engagement action can cause the power transmission breaking during operation mode changing process; 2) two speed gear cannot meet the requirements of whole vehicle speed range, especially at lower speed, therefore it makes the engine work at high vehicle speed; 3) this power train should not used in the vehicles which usually travel in urban area, because of speed limitation.

## Analysis on Power Train Operation Modes

There are six different working modes in this new powertrain, which are power battery charge mode, pure electric motor drive mode, Parallel hybrid drive mode, ICE power split mode, ICE drive mode and brake regenerative mode. These operation modes are described in detail with the help of sketch in the following. The arrows in the following figures are used to indicate the power flow direction of engine or electric motor.

Power battery charge mode: As shown in Figure 4 in this mode, two clutches are engaged, the synchronizer is in neutral position, and the vehicle is in stop state. Therefore if SOC of the power battery is lower than normal value, it is suggested that the engine should be started firstly, and engine power is just to drive the motor operated as a generator to charge the battery. When required SOC value is reached, the engine shut off and the vehicle is ready to be launched by pure electric motor. Because this two speed ratios are smaller which is not suit for vehicle launch condition, and the vehicle can only be launched with pure electric drive.

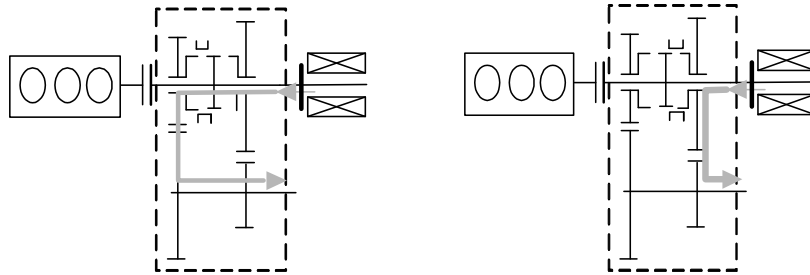


Figure 5. Pure electric motor drive mode (left for first gear, right for second gear).

Pure electric motor drive mode: As shown in Figure 5 when the vehicle is in launch state, first clutch is disengaged, second clutch is engaged, the motor can firstly drive the vehicle with first gear to get high driving torque, and then shift to second gear ratio at higher speed. Most of electric hybrid vehicle can reach set speed with pure electric drive depending on SOC of the power battery. With two speed ratio gear box, the motor can work with favorable gear to get higher efficiency according to its rotation speed.

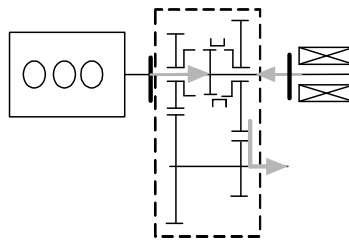


Figure 6. Parallel hybrid drive mode.

Parallel hybrid drive mode: As shown in Figure 6 this mode is for higher drive torque requirement conditions such as vehicle acceleration. The two clutches are engaged, the power from engine and electric motor from motor are coupled to drive the vehicle simultaneously to get enough driving torque. Because the limit of engine rotation speeds, this function cannot be used in slope climbing situation with lower vehicle speed. Therefore in most conditions, the vehicle using this powertrain system can only climb using pure electric motor driving.

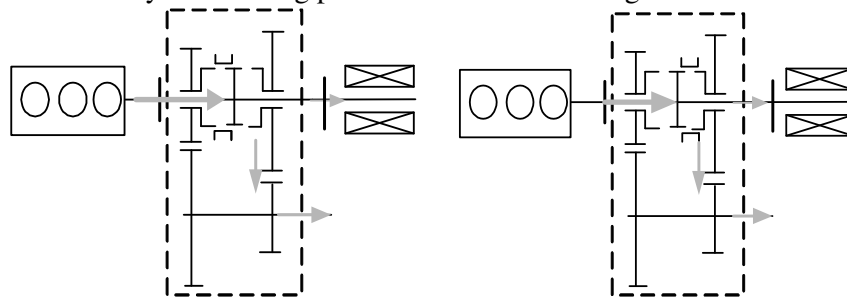


Figure 7. ICE power split mode (left for first gear, right for second gear).

ICE power split mode: As shown in Figure 7 the two clutches are engaged, the ICE generates the power to drive the vehicle and at the same time drive the motor to generate electricity. In this driving condition, most part of engine power is for vehicle driving, and the resident part can be used to drive the motor to charge the power battery, which can make the engine operated with higher fuel efficiency.

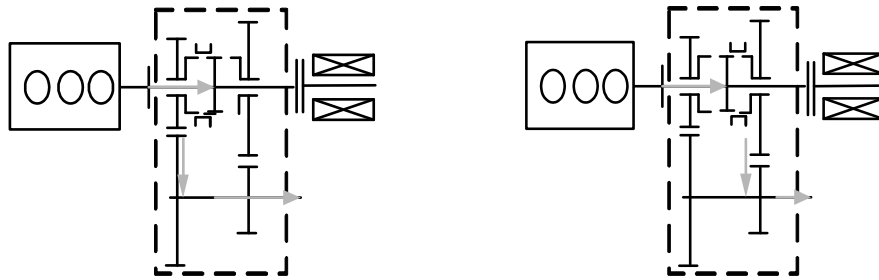


Figure 8. ICE drive mode (left for first gear, right for second gear).

ICE drive mode: As shown in Figure 8 the first clutch is engaged, and the second clutch is disengaged. The engine can drive the vehicle independently, and the electric motor does not work. The gear ratio can be selected basing on the vehicle speed to get higher fuel efficiency.

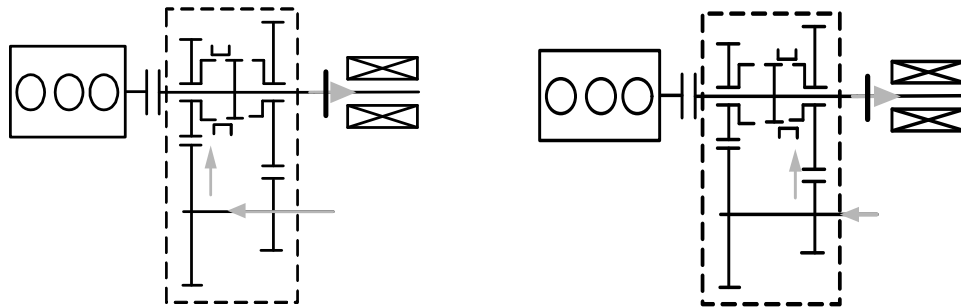


Figure 9. Brake regenerative mode (left for first gear, right for second gear).

Brake regenerative mode: As shown in Figure 9 when the vehicle is in braking condition, the first clutch is disengaged, second clutch is engaged and the motor operated as a generator. The engine can in idle or turnoff states which depend on its real control strategy. During braking condition, the vehicle kinetic energy can drive the motor to generate electricity and charge the power battery. If the SOC of battery reach its top limit, the motor cannot produce brake force then the vehicle braking function should be taken by conventional brake system.

## Summary

This new hybrid powertrain uses only one two-speed gear box, one motor and one engine to realize six different operation modes. Under optimized control strategy, it can meet the requirements of vehicles driving with satisfied dynamic performance, higher fuel efficiency and lower emission. At the same time the new system has simple structure, smaller size and lower cost.

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