Chapter 10
Plug-In Hybrid Power Train Engineering, Modeling, and Simulation

ABSTRACT

Chapter 10 presents the principles of the plug-in hybrid power train (PHEV) operation. The power trains of the battery-powered vehicle (BEV—pure electric) are close to the plug in hybrid drives. For this reason, the pure electric mode of operation of the plug in hybrid power train is very important. The vehicle’s range of driving autonomy must be extended. It means the design process has to be focused on energy economy, emphasizing electricity consumption. Simultaneously, the increasing of the battery’s capacity causes its mass and volume also to increase. Generally, it is not recommended. After many tests, one can observe the strong dependence between the proper multiple gear speed, the proper mechanical transmission adjustment, and the vehicle’s driving range, which in the case of the plug-in hybrid power train means long distance of a drive using the majority the battery’s energy. The mechanical ratio’s proper adjustment and its influence on the vehicle’s driving range autonomy is discussed in the chapter. Three types of the automatic mechanical transmission are depicted: the toothed gear (ball), the belt’s continuously variable transmission, and the planetary transmission system called the “Compact Hybrid Planetary Transmission Drive,” equipped additionally with tooth gear reducers, connected or disconnected by the specially constructed electromagnetic clutches. The number of mechanical ratios—gear speeds—depends on the vehicle’s size, mass, and function, which in the majority of cases means the maximal speed value.
INTRODUCTION

As was explained in Chapter 1, ‘plug-in hybrid’ (PHEV) power trains, considering their drive architecture, are the same (see and compare Figure 10 and Figure 11 in Chapter 1) as ‘full hybrid’ (HV). The difference is in control strategy, based on an extended range of the pure battery drive. This causes the state-of-charge, SOC, battery’s balance not to be obtained, as in the case of the full hybrid power train. This power train operation takes place when the battery is not so deeply discharged. In this case, the hybrid electric vehicle drives in pure electric mode. If the SOC decreases below the assumed value, the PHEV power train operates with advantage hybrid or pure Internal Combustion Engine (ICE) mode, which means the power train operates as a full hybrid system. This enables us to stabilize the battery’s SOC on a low, but approximately constant level, and continuing further driving similar to the full hybrid power train’s HV case. Of course, the capacity and accumulated energy of batteries are higher. The PHEV power train is the next step in hybrid technology development.

Figure 1 shows the difference between full hybrid HV and plug-in hybrid PHEV power train operation (Duvall, 2005; Mitsutani, Yamamoto, & Takaoka, 2010).

The plug-in hybrid power train, PHEV, operation is possible to split in three zones:

- In the first, (1) the externally supplied electrical energy recharges the battery.
- In the second, (2) the PHEV operates as a battery-powered electric vehicle EV and energy is supplied from the battery as a first priority. Anyway, conventional full hybrid HV power train operation is realized, when rapid acceleration or passing some steep terrain is required. The PHEV operates like a HV, which has a long driving range and lower fuel consumption. For this

Figure 1. The comparison of a full hybrid HV power train (a) and a plug-in hybrid PHEV power train (b), as it’s the battery’s state-of-charge (SOC) alteration versus time of vehicle driving cycle
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