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Plug-In Hybrid Electric Vehicles

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Abstract - Today transportation is one of the rapidly evolving technologies in the world. With the stringent mandatory emission regulations and high fuel prices, researchers and manufacturers are ever increasingly pushed to the frontiers of research in pursuit of alternative propulsion systems. Electrically propelled vehicles are one of the most promising solutions among all the other alternatives, as far as; reliability, availability, feasibility and safety issues are concerned. However, the shortcomings of a fully electric vehicle in fulfilling all performance requirements make the electrification of the conventional engine powered vehicles in the form of a plug-in hybrid electric vehicle (PHEV) the most feasible propulsion systems.

Keywords- PHEV, PSO, HEV, AER, CDR.

I. Introduction

Plug-in Hybrid Electric Vehicles (PHEV) links two major infrastructures, the transportation and the electric power grid. They offer a promise of significant reduction of fuel consumption, oil imports, and CO2 emissions by bringing other sources of energy into transportation. PHEVs are similar to conventional Hybrid Electric Vehicles (HEV) in that they utilize an electric motor and a gasoline engine as two drives to power a vehicle, but they have much larger batteries that can be charged from an electrical outlet. The electrical energy stored in the battery is used as the primary source of power on-board until the battery charge is depleted to a threshold level. This mode of powertrain operation is called the charge depleting (CD) mode or electric vehicle (EV) mode. After charge depletion to the threshold level the internal combustion engine is used to sustain the charge at this level. This is referred to as the charge sustaining mode (CS) mode. The all-electric range (AER) or the charge depleting range (CDR) of a PHEV is the distance over which the powertrain operates in EV or CD mode respectively and this has been recognized a very relevant attribute for PHEVs [1] [2] [3]. The engine fuel consumption during this mode is very low or zero. This has led to classification of PHEVs as PHEV 10 (A PHEV with 10 miles CDR/AER), PHEV 20 and so on. If pure AER is desired, a Series Hybrid Electric Vehicle configuration is particularly interesting. However, many design decisions have to be made to maximize the potential of a given configuration for a selected vehicle application. A hybrid electrical vehicle could be a variety of hybrid vehicle that utilizes the mixture of a standard combustion engine system and electrical system. The existence of electrical system is meant to boost the fuel economy, scale back waste material emissions and/or improve the performance.

II. Modelling

There are three main drivetrain configuration ns of Plug-in Hybrid electric Vehicles, namely: series, parallel and series-parallel (or power split).

Series Hybrid: Only the electrical motor is mechanically connected to the powertrain. The power provided by the engine is first converted to electrical energy through the generator and then converted to mechanical energy through the electrical motor. The engine is typically smaller in a series drivetrain because it only has to meet average driving power demands; the battery pack is generally more powerful than that in parallel hybrids in order to provide remaining peak driving power needs. This larger batter y and motor, along with the generator, add to the cost, making series hybrid more expensive than parallel hybrids.

Parallel Hybrid: In this configuration the engine and the electrical motor are both connected to the powertrain through torque coupling, speed coupling or torque and speed coupling, eliminating the inefficiency of converting mechanical power to electricity and back which takes these hybrids relatively more efficient o the highway. Yet, the same direct connection between the engine and the w heels that increases highway efficiency compared to a series hybrid does re duce, but not eliminate, the city d riving efficiency benefits (i.e. the engine operates inefficiently in stop-and-g driving because it is forced to meet the associated widely varying power demands).

Series-Parallel Hybrid (Powers split hybrid*):* This drivetrain merges the advantages and complications of the parallel and series drivetrains. By combining the two designs, the engine can both drive the wheels directly (as in the parallel drivetrain) and be effectively disconnected from the wheels so that only the electric motor powers the w heels (as in the series drivetrain).

III. Optimization Considerations

A vehicle design optimization presents many complexities. A vehicle presents a system of many components working together in very intricate ways. The powertrain of a hybrid electric vehicle (HEV) is a link of an internal combustion (IC) engine, electric motor, transmission, wheels and axles, and battery pack. Each component has several parameters and possible designs. For example, a battery pack can have different capacities, chemistries, and voltages. Varying a single parameter typically has an effect on the whole system design. Also, compatibility between different components with varying parameters must be checked. For example, it must be ensured that the battery pack has enough available power to supply the peak electric motor power and there must be a check to see if the transmission can withstand the torque from the motor and engine. Also, there must be a way of evaluating the effectiveness of any given design. The vehicle design must adhere to a set of performance constraints, such as 0-60 mile per hour (mph) acceleration time and grade-ability constraints. Also, the vehicle design must be evaluated for cost to determine the minimum cost design. There could be many other figures of merit besides lowest cost, such as minimum gasoline consumption, minimum weight, or best performance.

IV. Vehicle Model

The mathematical model of the vehicle is constructed as for the following three major phenomenons: Grade, aerodynamic drag and rolling resistance.

Grade force: First of all, the grade force (Fg) that the vehicle has to overcome has a significant impact on the dynamic model of the vehicle. This grade force is calculated using Newton's second law of motion, Equation 1.4. Depending on various variables, such as; vehicle mass and grade angle, the grade force can change, which has a large impact on the force required to drive the vehicle, and can result in changing the accuracy of the dynamic model.

$$F_g = g\, m_v \, \sin(\tan^{-1}(\aleph)) \tag{1.4}$$

where g is the gravitational acceleration, m_v is the vehicle mass and $\aleph$ is the road grade.

Aerodynamic drag: Second major phenomenon is the aerodynamic drag. As the vehicle moves it is resisted by the air surrounding the vehicle and creating a resistive force known as aerodynamic drag.

Rolling resistance: The last one is the rolling resistance, which relatively has a small impact compared to the other two. This resistive force is created because of the deformation of the tires at the point of the contact with the ground during rolling motion.

V. Conclusion

The paper describes the Plug-In hybrid electric vehicles considerations. The gradient free algorithm, e.g., the particle swarm optimization was used to determine the optimal configuration of the component sizes to achieve a better fuel economy and emission levels.

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