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Series and Parallel Hybrid Transmission in Electrical Vehicle Using Matlab/Simulink

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Abstract

A hybrid electric vehicle (HEV) combines the strengths of ICE vehicles with EVs to provide a more versatile and convenient driving experience. Because it combines series and parallel architectures, the series-parallel hybrid has the best qualities of each and can function in more ways than any architecture can on its own. This paper uses Matlab/Simlunk to create a series-parallel HEV model that includes simulations of the vehicle's longitudinal dynamics, tyres, an internal combustion engine (ICE), batteries, a DC/DC converter, motor and generator drives, a speed coupling device (planetary gear mechanism), and a torque coupler. Poor fuel economy and pollution are problems plaguing conventional vehicles powered by internal combustion engines (ICEs) due to factors like inefficient hydraulic transmission in urban stop-and-go driving and a mismatch between engine fuel efficiency characteristics and the real operation requirement. The HEV control system is described. Furthermore, the efficiency of the HEV model is confirmed by simulation results.

Keywords: Hybrid electrical, Electrical vehicle, Series-parallel hybrid electrical vehicle, Simulation

Introduction

Due to factors like the inefficiency of the hydraulic transmission in urban areas and the dissipation of kinetic energy during braking, conventional vehicles powered by internal combustion engines (ICEs) are inefficient and polluting. Battery-powered electric vehicles (EVs) have several benefits over internal combustion engine (ICE) vehicles, including great energy efficiency and minimal environmental pollution, but their operating range per battery charge of is significantly less competitive than that of ICE vehicles. The benefits of internal combustion engine (ICE) vehicles and the advantages of electric vehicles (EVs) are combined in a hybrid electric vehicle (HEV), which employs both types of electricity. HEVs may be broken down into three distinct categories based on the way in which power is transmitted: series hybrids, parallel hybrids, and series-parallel hybrids. Among these is the series-parallel hybrid, which is a blend of the two structures and so has the advantages of both while also offering greater flexibility in terms of how it may be put to use. P [1]-[5]P . In this paper, we present a Matlab/Simlunk-based series-parallel HEV model that includes simulations of the vehicle's longitudinal dynamics, tyres, an internal combustion engine (ICE), batteries, a DC/DC converter, motor and generator drives, speed coupling devices (planetary gear mechanisms), and torque coupler devices. The HEV's control system is described. Moreover, the success of the HEV model in simulation has been shown.

Solutions to urban climate pollution, greenhouse gas emissions, and the depletion of scarce fossil fuel sources, such as electric automobiles powered by locally produced energy, are maturing as practical options. Energy production at integrated plants is well-established to be more efficient than that of the ubiquitous internal combustion engines, and their pollutants are also far more amenable to regulation. A further advantage of electric vehicles is that they can convert kinetic energy into electrical power and store it for later use, even while stopping or coasting. More than a hundred years later, the interest of business, academia, and politicians in electric cars as viable solutions for urban transportation is beginning to be verified by all of the advantages of electric vehicles. Now, businesses and universities are working to find solutions to the major obstacles that prevent electric cars from being widely used. Key obstacles include increasing the battery pack 3's useful life while decreasing its energy consumption, strength capacity, weight, and cost. Nevertheless, it is just as crucial to model and optimise a number of other components of electric automobiles because of the significant effect they have on the vehicles' performance, driving dynamics, and safety. In this setting, skills in electric vehicle modelling and optimisation are becoming more important. The origins of modern battery-operated electric vehicles may be traced back to the early twentieth century, when the first automobiles were built. Regrettably, the inexpensive cost of fossil fuels curtailed any impetus such vehicles may have had. However, the preceding 10 years have seen a spike in the Electric Vehicles company, as they have demonstrated to be a rising market segment in the travel industry. Reducing the negative impact on the environment caused by burning fossil fuels, lowering transportation operating costs, and increasing market participation in innovation have all been major factors [2]. Even if gasoline prices for internal combustion engine vehicles were to drop, manufacturers' excitement about electric cars would likely still lead to rapid expansion of the market. Automotive electrification, in particular, has now formed the foundation for the adoption of current car technologies such as semi-autonomous and even autonomous driving.

2 Series-parallel HEV Model

The diagram of series-parallel HEV model is shown in Fig. 1.

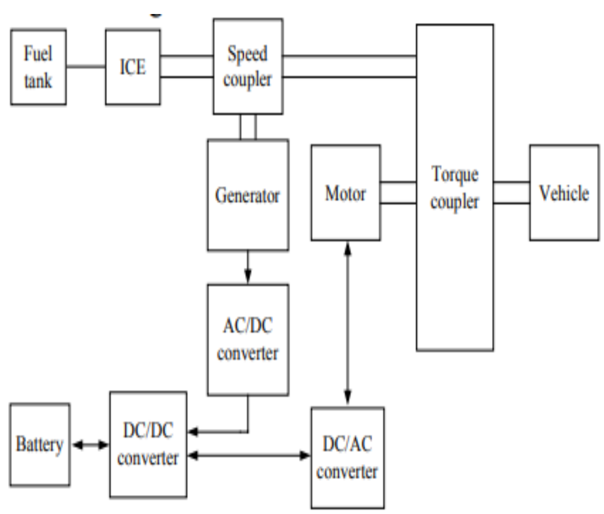

Figure 1: The diagram of series-parallel HEV

The models of the vehicle's longitudinal dynamics, the tyres, the internal combustion engine, the battery, the DC/DC converter, the motor drive, the generator drive, the speed coupling device (planetary gear mechanism), and the torque coupler device make up the series-parallel HEV model. Following that, we'll explain these supplementary structures.

2.1 Dynamic Model of the Longitudinal
As can be seen in Fig. 2, the longitudinal dynamic model of the HEV is a two-axle vehicle with four identically sized wheels that moves forward or backward along its longitudinal axis, where m is the mass of the vehicle, is the angle of inclination, A is the effective frontal cross-sectional area of the vehicle, VB xB is the longitudinal vehicle velocity, FB xfB and FB xrB are the longitudinal forces on the vehicle at

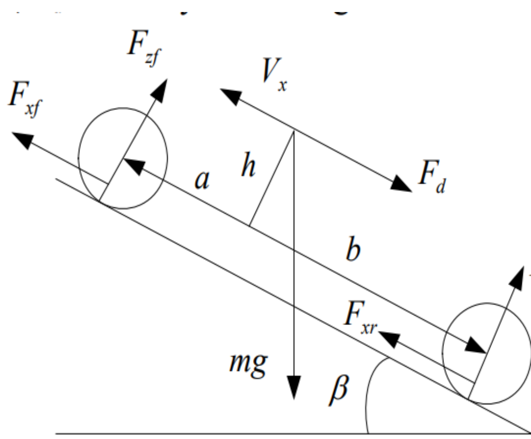

Figure 2: Vehicle dynamics model

2.2 ICE model
The ICE prototype is a gasoline-powered, spark-ignition motor controlled by a variable-speed mechanical governor. The throttle signal regulates the engine's speed and, by extension, the amount of torque it produces. Ratio of Top Engine Speed to Maximum Torque

3. HEV Control System
Here is what we can deduce about the HEV's control system: Pure electric driving mode (ICE off) is used in a HEV when the reference power is negative (braking mode). In this case, both the reference ICE torque and generator torque are 0 lb-ft. As the sole source of propulsion, the vehicle's engine also doubles as a generator, feeding the vehicle's battery with electricity. If reference power is positive, the vehicle is cruising. As soon as the reference power rises over the maximum, the HEV enters hybrid drive mode, with the ICE active. Planetary gear unit splits the ICE's output in half. A torque coupling mechanism transfers mechanical energy from one component to the other, propelling the vehicle. As an added bonus, the ratio between ICE torque and generator torque is constant.
An HEV is also considered to be operating in hybrid drive mode if the reference power is positive but lower than the upper limit and the SOC is lower than the lower limit. One half of the ICE powers the wheels, while the other half spins a generator to power the car's engine and recharge the battery. The HEV will be in all-electric mode if the reference power is positive and lower than the upper limit and the SOC is higher than the lower limit. As of right now, simply the motor propels the car.

4. DISCUSSION & RESULTS
There were no major distinctions between the two methods when it came to designing the vehicle's parts. Modelica, an object-oriented programming language, enabled simulation work to be done with the Dymola software from Dassault Systems. One of its benefits is that it can quickly include functionality from a wide variety of physical domains into a unified architecture. This is particularly relevant to the electrical and mechanically connected systems seen in electric vehicles. Thus, a library of component models has been developed for the modules to use in the intended job. The various moving components of a vehicle may be studied by using the whole vehicle model. [19] Several newly developed and built library modules have also been used to investigate the impact of these innovative electric car technologies. It's possible to investigate the energy consumption and efficiency gains associated with,

say, a range extender or a hybrid energy storage device with double layer capacitors. The majority of this data was put to use in creating the latest model of car. The project team is now working on the compositional strategy for the modern vehicle, using the truck model as an example. Its modular design might be used in the production of futuristic automobiles. The model was used to choose electric vehicle propulsion technologies.

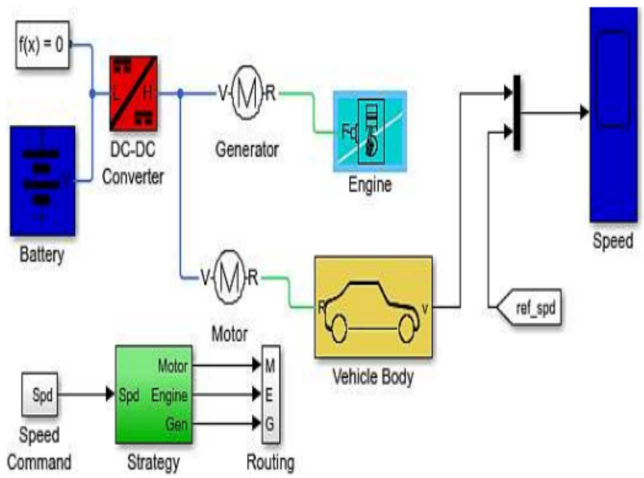

Fig. 3: Simulink Model of Hybrid Series Transmission

The energy need for the 100 second simulation is determined by the input speed and torque of the driving cycle. Remember that while both the speed and torque are increasing, the motor is moving forward. Reduced torque causes the motor to enter the generator mode of operation known as the fourth quadrant. Another method that may be used to identify this strategy is the use of the negative power value or the portion of the power curve that is below the y-axis. Such operations make advantage of the engine's four-way control. Two simulated scenarios are chosen to validate the proposed method, both of which provide a satisfactory account of the expected outcomes.

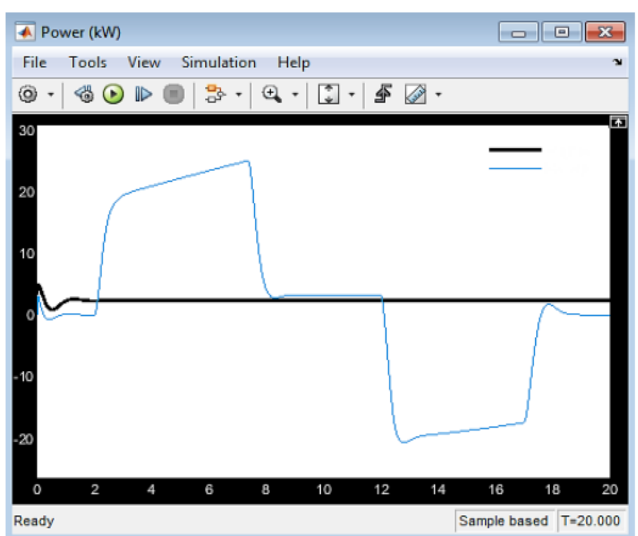

Fig 4 Modeling the power output of a hybrid series transmission system in Simulink yields the following results

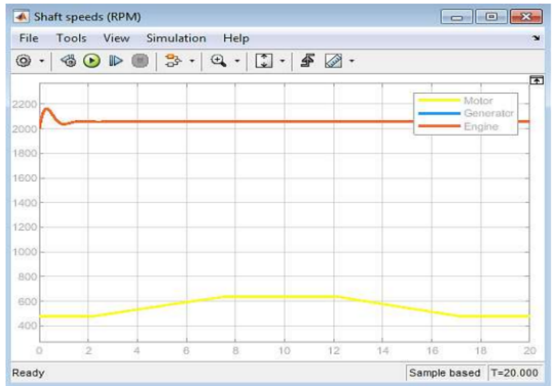

Fig. 5: Simulink Model Result of Shaft Speed of Hybrid Series Transmission System

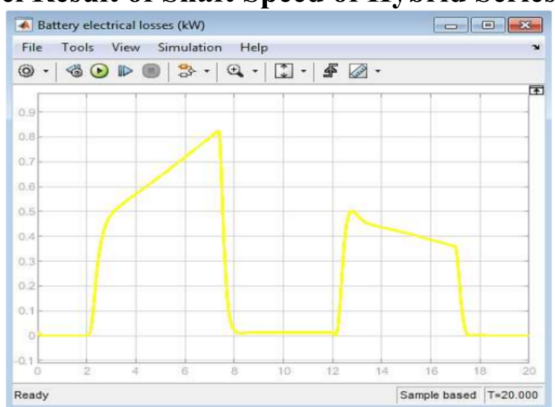

Fig. 6: Simulink Model Results of Battery Electrical Losses of Hybrid Series Transmission System

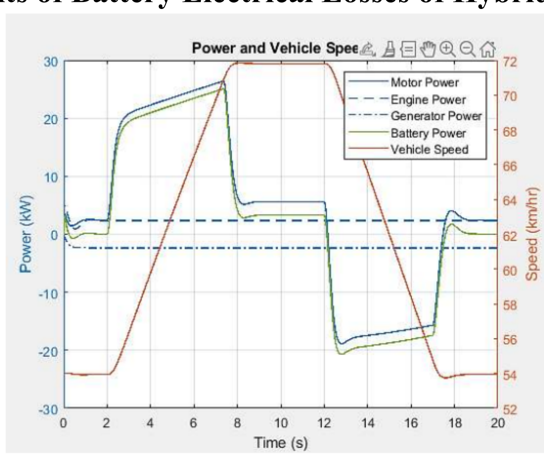

Fig. 7: Simulink Model Results of Power and Vehicle Speed of Hybrid Series Transmission

Some simulation findings found for assessments of system model for hybrid series transmission are as follows: Fig.3 shows the simulation results of the hybrid series transmission system's engine power and battery power. Blue line represents the engine power, which is about peak to peak 50kW AC power, and black line represents the constant as approx. 5kW battery power of hybrid series transmission system.

• Fig.4 displays the shaft speed simulation results of a hybrid series transmission system. The brown line represents a constant engine speed of around 2050 revolutions per minute, while the yellow line represents a range of motor speeds from about 450 to 620 revolutions per minute. Battery electrical losses of the hybrid series transmission system were simulated and found to vary from 0 kW to 0.82 kW, which is quite close to the nominal value for this kind of system setup. 39 Fig. 5.6 displays the results of a simulation of the fuel consumption of a hybrid series transmission system, which may be described as a linear function of time. Figure 5.7: Power and vehicle speed as simulated by a hybrid series transmission system. The red line depicts the vehicle's speed as it increases from 54 kilometres per hour to 72 kilometres per hour and then remains at that speed for a little while. The blue line represents the 50 kW of peak-to-peak AC motor power. And the wavy blue line represents the engine's consistent power output of about 13 kW. Additionally, the generator's constant power is shown by the deformed blue line with dot, which is around 2.5 kW. Moreover, the battery power is shown by the yellow line, which ranges from -22 kW to 22 kW in this picture. As can be seen in Fig. 7, the simulation results of the hybrid series transmission system's electrical losses and vehicle speed are shown graphically. The red line illustrates the vehicle's speed progression from 54 km/h to 72 km/h, when it remains still for a brief while. The total electrical component losses are shown by the blue line and range from 0 to 1.8 kilowatts. The motor losses, seen by the wavy blue line, range from zero to one point five hundred and five kilowatts. In addition, the generator losses, shown by the wavy blue line with the dot, range from zero to one point eighteen hundred and eighty-five kilowatts. Moreover, the performance of the batteries' losses is shown by the green line, which ranges from 0 kW to 0.8 kW.

Conclusions

In this paper, we use Matlab/Simlunk to construct a series-parallel HEV model that accounts for the vehicle's longitudinal dynamics as well as the tyre model, internal combustion engine model, battery model, DC/DC converter model, motor drive model, generator drive model, speed coupling device model (planetary gear mechanism), and torque coupler device model. The HEV's control system is described. Moreover, the success of the HEV model in simulation has been shown.

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