International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 05 Issue: 06 | June - 2021 ISSN: 2582-3930

Modelling and Simulation of Hybrid Electric Vehicle

Anushree Bandurkar , Nikhita Khobragade , Sumit Laturkar ,

Sagar Bhaisare

Department of Electrical Engineering

Karmavir Dadasaheb Kannamwar College of Engineering

Nagpur, Maharashtra

Abstract - This Paper Presents a Modelling and Simulation of Series-Parallel Hybrid Electrical Vehicle (SPHEV) by using MATLAB/Simulink. Hybrid electric vehicle can save fuel and reduce environmental pollution as compared to conventional vehicles. Hybrid electric vehicle uses internal combustion engine and electrical power, which has the advantages of both ICE vehicle and electrical vehicle. Series-Parallel Hybrid is the combination of series and parallel structure configuration drivetrain; thus, it possesses the major features of both and more abundant. A full drivetrain system of a Series-Parallel Hybrid Electric Vehicle model is developed including five major components: Internal Combustion Engine (ICE), Motor Generator (MG), batteries and Power Split Device (PSD / Planetary gear mechanism) along with the vehicle longitudinal dynamics. All aspects of rotational inertial dynamics, friction, damping and stiffness properties are considered. MATLAB/Simulink Software is used for the graphical simulation of HEV.

***Key Words* - Hybrid Vehicle, Series-Parallel Hybrid Electric Vehicle, Modelling and Simulation, MATLAB/SIMULINK.**

I. INTRODUCTION

Rising energy costs, the end goal is for zero-emission cars to be available (ZEV). However, battery and fuel cell technologies have not yet been sufficiently designed to satisfy basic requirements such as speed and driving range, and developing the necessary infrastructure is neither simple nor cost-effective .While hybrid electric vehicles (HEVs) were introduced as a stopgap measure before full electric vehicles took over the industry, HEVs have already proven to be a viable option for commercialising super-low-emission vehicles. The fundamental concept behind hybrid technologies is to combine two or more power sources in order to take advantage of the advantages of each source's unique characteristics while avoiding the drawbacks of separate systems. Based on this concept, a hybrid electric vehicle (HEV) that incorporates a traditional internal combustion engine (ICE) and an electric motor as propulsion units has the benefits of both ICE and EV vehicles thus overcoming some of the drawbacks of the individual systems.

Traditional ICE vehicles have a long range and decent driving efficiency due to the high energy density of petroleum fuels, but they have certain drawbacks such as low fuel economy and heavy pollutant emissions. The reasons for poor fuel economy performance include ICE operating range changes based on driving conditions, frustration with full energy range operation, and low engine and transmission reliability in stop-and-go driving cycles .However, battery-powered electric vehicles have a distinct advantage in “regenerative braking,” which is described as the accumulation of kinetic energy in the brakes rather than its dissipation during braking operation. Furthermore, by its very essence, an electric motor has a high efficiency. Pure electric cars, on the other hand, have issues with energy storage and the "State of Charge" (SOC) phenomenon, which indicates the level of charge and has an effect on the reliability of battery operations as well as charging and discharging power levels. In addition to lowering emissions and fuel consumption, optimising ICE service results in longer maintenance intervals and lower costs due to less oil adjustments, exhaust repairs, and brake pad replacements.

II. HEV DRIVETRAIN ARCHITECTURE

Series-Parallel Drivetrain

Series parallel hybrid uses the advantageous of both series and parallel configurations. It includes an extra generator different from the parallel configuration and unlike the series configuration the engine has mechanical coupling directly with electric motor. The parallel drive train is made up of two independent clutches that are mechanically coupled to the electric motor and internal combustion engine via the drive shaft. Unlike traditional ICE vehicles, electric motors assist the ICE in achieving typical HEV characteristics such as low emissions and fuel efficiency. The mechanical coupling between the motor and the engine can take two forms: “speed coupling” and “torque coupling” to meet various design specifications, and this simple criterion can be used for the more complicated systems described in the following drivetrain categories separately or both on the same system). The series HEV is more of an EV with the addition of an internal combustion engine to help charge the battery. It is the most common and straightforward kind of HEV drivetrain

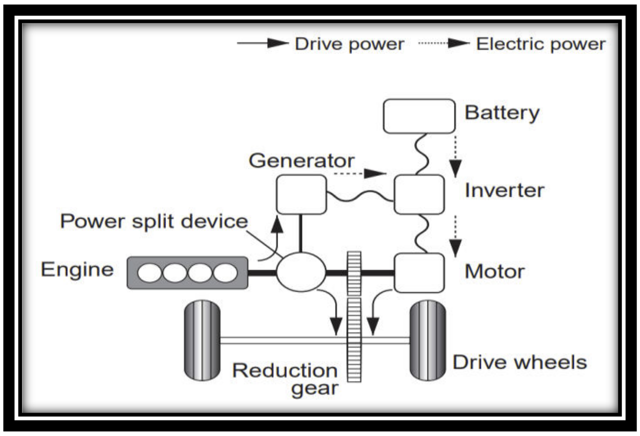


Figure 1:-Series-Parallel Hybrid

1.Energy Management System

Control systems range in sophistication from the most basic, such as "on-off control," to the most advanced, such as real-time optimization and driving characteristic estimation. The applied strategy's core concept is energy conservation or power break, which is accomplished by the use of several sub-elements such as motor, engine, brake, transmission, and clutch controllers. If the aim is to accomplish the best possible energy management, some simple considerations should be made along the way:

- Getting the maximum efficiency or minimum emission region/point of ICE on the torque/speed map according to demand.

- Satisfying the maximum battery efficiency related with energy demand rate and SOC

- Safe battery region satisfaction, keeping the SOC above from a certain value and below the maximum permissible value while propulsion, charging and regenerative braking.

- Power split between the electric motor (so the battery) and the engine according to system parameters.

- Determination of task of the electric motor whether to work as motor or generator considering the power demand, engine speed, and SOC.

- Engine shut down below a specified limit, avoiding low efficiency region.

- Avoiding/minimizing engine start operation and sudden speed changes to keep efficiency on the desired level.

- Some additional, nontraditional methods such as driving characteristic calculation and parameter optimization related to it, road characteristic prediction by a help of GPS and built-in map database and changing system parameters by global real time optimization.

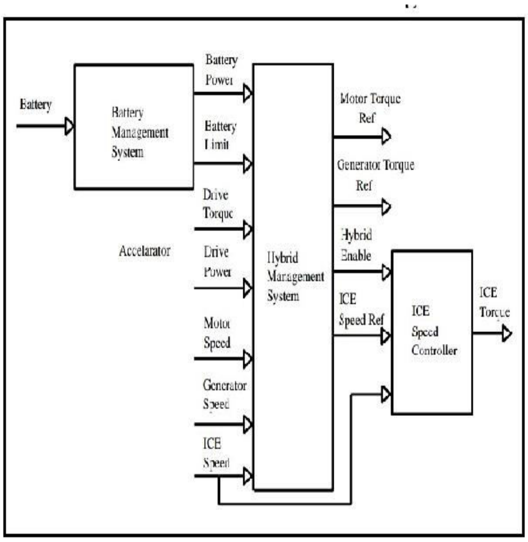


Figure 2:- Energy Management System

2.Electrical Subsystem

Hybrid vehicle system, the propulsion system mainly comprises the following components: prime mover; electric motor with DC/DC converter, DC/AC inverter, and controller; energy storage system; and transmission system. The prime mover of a hybrid vehicle is its main energy source, which generally is one of gasoline, diesel, or fuel cells. The electric motor is one of the most important components in a hybrid vehicle. The energy storage system, one of the most important subsystems in an hybrid electric vehicle (HEV), consists of an energy storage pack; a voltage, current, and temperature measurement (VITM) module; a cell balancing circuit; and a cooling system.

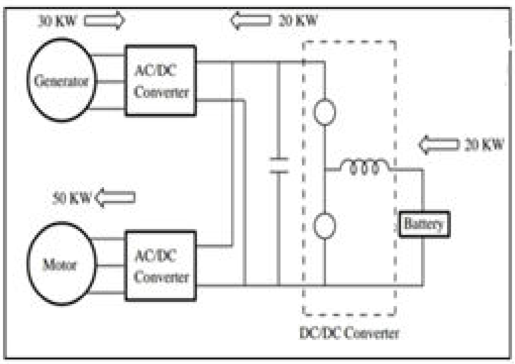


Figure 3:- Electrical Subsystem

1. The electrical motor is a 500 V dc, 50kW interior Permanent Magnet Synchronous Machine (PMSM) with the associated drive. This motor has 8 pole and the magnets are buried. A flux weakening vector control is used to achieve a maximum motor speed of 6000 rpm.
2. The generator is a 500 V dc, 2 pole, 30kW PMSM with the associated drive. A vector control is used to achieve a maximum motor speed of 13000 rpm
3. The battery is a 6.5 Ah , 200 V dc , 21kW Nickel – Metal –Hydride battery.
4. The DC/DC converter is voltage regulated. The DC/DC converter adapts the low voltage of the battery to the DC bus which feeds the AC motor at a voltage of 500V.

3.Internal Combustion Engine

In this configuration, fuel is injected into either the intake manifold or the combustion chamber, where it is combined with air, and the air/fuel mixture is ignited by the spark from a spark plug. Internal combustion engine is one of the energy sources in a hybrid drive system. A model is needed to simulate generated power from the fuel as mechanical shaft work and it should be easily implemented to different drivetrain configurations as a black box power source for the calculation of vehicle performance, fuel consumption, and emission values. A look up table based model is used which is provided by ADVISOR in MATLAB Simulink platform. The Internal Combustion Engine subsystem models a 57 kW at 6000 rpm gasoline fuel engine with speed governor.

Figure 4:- Internal Combustion Engine

4 .Planetary Gear System

Volume: 05 Issue: 06 | June - 2021 ISSN: 2582-3930

In a combustion engine, the engine generates torque, which is used for acceleration, and power in a narrow band of engine speeds, or gears. In order to accelerate, the rpm must be kept relatively high to gain the necessary torque and power that's required. The gears allow you to keep the power between a set amount so that you can gradually speed up and slow down while still having enough torque to do so. First gear can only get you up to a certain speed before the amount of rpm becomes too much and you need to move up to second gear.

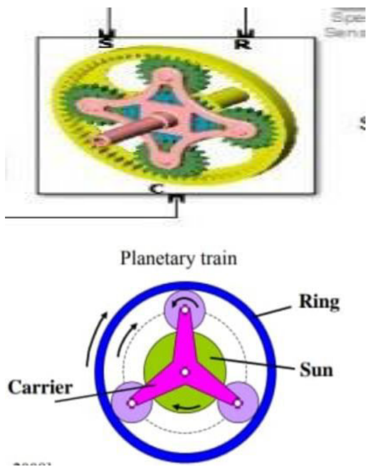


Figure 5:- Planetary Gear Subsystem

5.Vehicle Dynamics

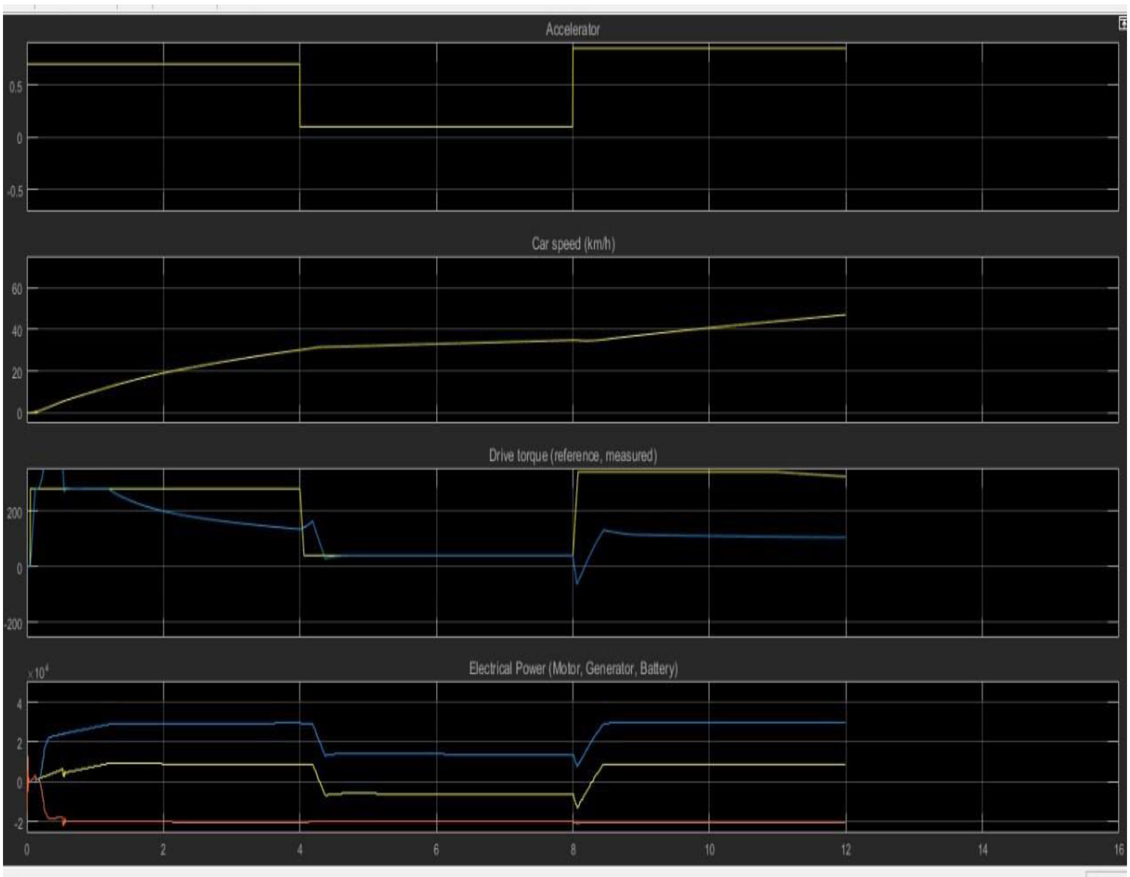
The focus is on friction and aerodynamic drag interactions with weight and grade ability factors accounted in the equations. The vehicle dynamics subsystem models all the mechanical parts of the vehicle.

1. The single reduction gear reduces the motor's speed and increases the torque.
2. The differential splits the input torque in two equal torque for wheels.
3. The tires dynamics represent the force applied to the ground.
4. The vehicle dynamics represent the motion influence on the overall system.
5. The viscous friction models all the losses of the mechanical system.

III. SIMULATION RESULT

The simulation shows different operating modes of the HVE over one complete cycle:

1. Accelerator
2. Car speed (km/h)
3. Drive torque (reference ,measured)
4. Electrical power (motor , generator, battery)



Engine Drive Mode: - In this state, the engine is drives the vehicle without the synergy of the MG output power. The MG switch is turned off and the brake band of the sun side BB2 is applied to prevent the engine power from leaking to the MG. the throttle is set to 30%. The engine speed accelerating from its idle speed at 800rpm to 1500rpm while the vehicle accelerating to its final speed.

MG Recharging Mode: - The MG is driven by the engine in order to function as a generator. The vehicle is stopped and the whole engine output is used to drive the MG to charge the batteries. The brake band of the ring side BB1 is activated and that of the sun side BB2 is deactivated. The throttle valve is set to be 5% as expected in similar idle condition of the engine. The engine speed accelerating from its idle speed at 800rpm to 1100rpm which is the limit of the idle range, and the MG speed reaches 3850 rpm. The batteries initial state of charge are set to be 50%.

ICE-MG Synergy Mode: - In this mode, both the ICE output and the MG output are used to empower the vehicle. Both brake bands of the sun and ring sides are deactivated so that they can deliver power to the vehicle at the same time. The throttle valve in this mode is set to 30% as in Engine Drive Mode, so the consumed power in both states can be compared, the engine accelerating to 1500rpm and the vehicle accelerating to 28.54m/s. A negative value of the MG rpm, which indicates its rotational direction to be opposite to those of ICE and Vehicle's propeller shaft.

IV. CONCLUSION

Hybrid Electric Vehicles are one of the promising challenges in energy management applications. Exact simulation and control of the possible states of hybrid power train can achieve many numerous virtues such as fuel consumption optimization and emissions reduction. The proposed model in this work shows some promising results for the different modes of operation matching the real case. As the model behaved in an accepted matter, many optimization and control methods can be applied on the model to experience their effect on the overall vehicle's efficiency.

REFERENCES

[1] K. T. Chau and Y. S. Wong, "Overview of power management in hybrid electric vehicles,"

Energy Conversion and Management, vol. 43, pp. 1953-1968, 2002.

[2] Mehrdad Ehsani, Yimin Gao, Sebastien E. Gay, and Ali Emadi, Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design.: CRC Press, 2004.

[3] US Department of Energy. Last accessed in September, 2012 [Online]. http://www1.eere.energy.gov/vehiclesandfuels/technologies/systems/hybrid_electric_vehicles.ht ml

[4] C.C. Chan, "The State of the Art of Electric, Hybrid and Fuel Cell Vehicles," in Proceedings of IEEE, vol. 95, 2007.

[5] Allen E. Fuhs, Hybrid Vehicles and The Future of Personal Transportation. Florida, United States of America: CRC Press, 2009.

[6] Ian John Albert, Elvir Kahrimanovic, and Ali Emadi, "Diesel Sport Utility Vehicles With Hybrid Electric Drive Trains," IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, vol. 53, no. 4, pp. 1247-1256, July 2004.

[7] D. Karbowski, S Pagerit, J Kwon, and A Rousseau, "“Fair” Comparison of Powertrain Configurations for Plug-In Hybrid Operation Using Global Optimization," SAE International, ISSN 0148-7191, 2009.

[8] Vincent Freyermuth, Aymeric Rousseau, and Eric Fallas, "Comparison of Powertrain Configuration for Plug-in HEVs from a Fuel Economy Perspective," in Proceedings of SAE World Congress, Detroit, 2008.

[9] Matthew R. Cuddy and Keith B. Wipke, "Analysis of the Fuel Economy Benefit of Drivetrain Hybridization," in Proceedings of SAE International Congress & Exposition, Detroit, Michigan, 1997.

[10] D. W. Gao, C. Mi, and A. Emadi, "Modeling and simulation of electric and hybrid vehicles," in Proceedings of Proceedings of IEEE, 2007, pp. 729-745.

[11] K.B. Wipke, M.R. Cuddy, and S.D. Burch, "ADVISOR 2.1: A User-Friendly Advanced Powertrain Simulation Using a Combined Backward/Forward Approach," IEEE Transactions on Vehicular Technology: Special Issues on Hybrid and Electric Vehicles, vol. 48, pp. 1751-1761, November 1999.

[12] T. Markel et al., "ADVISOR: a systems analysis tool for advanced vehicle modeling," Journal of Power Sources, vol. 110, pp. 255-266, 2002.

[13] D. Assanis et al., "Optimization Approach to Hybrid Electric Propulsion System Design," Mechanics of Structures and Machines: An International Journal, vol. 27, no. 4, pp. 393-421, April 2007.