IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X
PP. 65-71
www.iosrjournals.org

Modelling And Simulation Of Regenerative Braking System For Light Commercial Vehicle- A Review

Shubham Shewate[1], M. A. Kumbhalkar[#], Yogesh Sonawane[2], Tushar Salunkhe[3], Samrat Savant[4],
[1,2,3,4]*Student, Mechanical Department, JSPM Narhe Technical Campus, Pune, India*
[#]*Assistant Professor, Mechanical Department, JSPM Narhe Technical Campus, Pune, India*

Abstract: *In this paper, Regenerative braking strategy for hybrid vehicles is studied. As the usage of fuel resources increasing day by day, the lack of fuel and environmental pollution become a serious problem. For such Problems, Hybrid Electric Vehicles are one of the better solutions. As we know that energy can neither be created nor be destroyed, it can be just converted from one form to another. Regenerative braking is one of the techniques adopted by HEVs in which, Kinetic energy is converted into electrical energy and use it directly or store in battery for further use. This Paper includes the study of HEVs and Regenerative braking system. Also, the study of modelling and simulation for regeneration model developed in modern simulation tools has been introduced.*

Keywords: *Hybrid Vehicles, Regenerative Braking Strategy, Simulation.*

I. INTRODUCTION

Transportation is important in today's world. It increases use of fuels which causes depletion of fuel increase in transportation cost and environmental pollution. The solution for the above problems is the use of hybrid electric vehicles which improves the performance of the vehicle. It uses two or more power sources to drive the vehicle without affecting their efficiency. In HEVs regenerative braking is used to increase fuel economy and reduce emissions. Mechanical, Hydraulic, Hydro-electric, electric are the types of regenerative braking system.

Many researchers, investigated optimum control strategy for regenerative braking with the help software like ADVISOR in MATLAB environment. This paper contains the study of regenerative braking simulation for diesel hybrid vehicle using GT-software as a simulation tool. In this software, we can use typical diving cycles like HWY, New European Driving Cycle (NEDC), SFTP-US06. Fuel economy and emission results in form of graphs are obtained to check the performance of HEV.

Paper presented by M.K Yoong[1] includes the working principle and braking controller for RBS to increase its efficiency. Paper presented by SONIYA.K. MALODE, R.H. ADWARE[2] includes an introduction and working principle of the regenerative braking system in which all braking modes are described. Paper presented by PULKIT GUPTA, ANCHAL KUMAR, SANDEEPAN DEB, SHAYAN[3] gives the difference between conventional braking and regenerative braking system, its advantages disadvantages and applications.
John William Miller[4] gives the detailed architecture and operation of a tunable single axle RBS for use in Challenge X vehicle.

In a thesis is presented by Brian Su-Ming Fan[5], Modelling and simulation of HEV are done by using MATLAB/Simulink and ADAMS. Fuel economy of HEV and the conventional vehicle is compared using EPA New York City Cycle (NYCC) and the Highway Fuel Economy Cycle (HWFET). Sanjai Massey[6] present a paper on modelling and simulation of HEV, which is based on UDDS (urban dynamometer driving schedule) to simulate real driving conditions. A MATLAB/Simulink model Is developed in this paper. Ajinkya Gore, S.B. Sanap, R. V. Mulik[7] Developed a regeneration model in GT-Suite simulation tool and also give a brief introduction about HEV and RBS.

II. HEV AND RBS

1. Hybrid Electric Vehicle: -

The hybrid electric vehicle combines any two power sources to drive the vehicle. Generally, diesel/electric, gasoline/flywheel and fuel cell (FC)/battery combinations are used[10]. On the basis of Architecture, there are three types of HEV explain below.

Figure 1 shows Series configuration HEV. It consists of only one energy converter. IC engine acts as a prime mover. It drives an electric generator which converts mechanical energy to electric energy which is stored in a battery for further use. The electric motor receives electric energy and drives the wheels to propel the vehicle. In series HEV, Generator gives maximum electrical energy because the engine runs at its best efficiency during the stop and go of city driving. During highway driving the energy loss is more, therefore, the system gives lower efficiency.

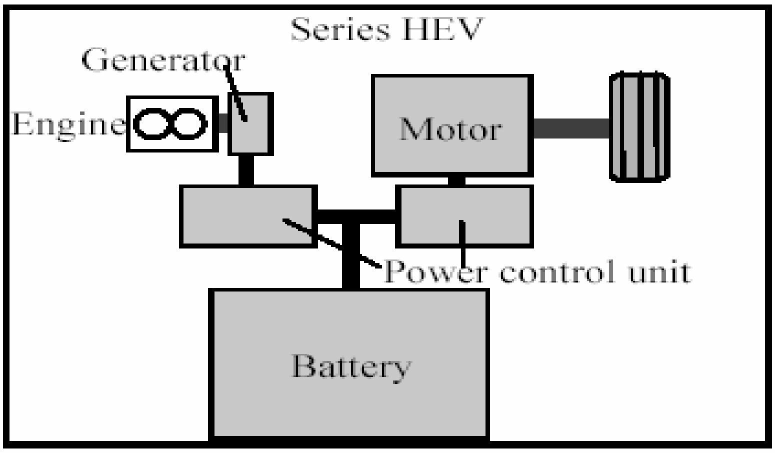

Figure 1: Schematics of Series Hybrid Electric Vehicle [9]

Figure 2 shows Parallel configuration HEV. It switches between the internal combustion engine and electric motor drive to drive the vehicle. In this configuration, vehicle gives high efficiency during highway driving condition. The power requirements of the electric motor in parallel HEV are lower than series HEV because IC engine complements to the total power demand of the vehicle.

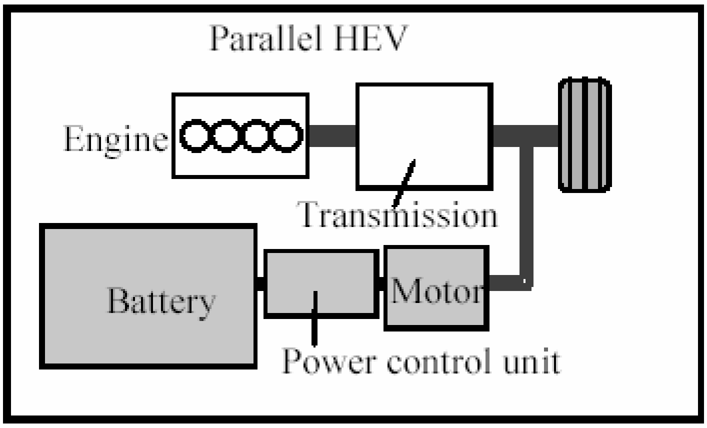

Figure 2: Schematic of a Parallel Hybrid Electric Vehicle [9]

In series-parallel configuration (Split Type) HEV the IC engine is used to drive the vehicle as well as to charge the battery. The architecture of this configuration is highly complicated.

2. Regenerative Braking System: -

The regenerative braking system is energy recovery mechanism used in HEVs. When brakes are applied the vehicles slow down, the kinetic energy is simply get released in form of heat and becomes useless[3]. RBS convert this energy into electric energy or mechanical energy and use it to drive the vehicle. It improves performance and efficiency of the vehicle. There are two types of RBS explain below

Figure 3 shows the Hydraulic RBS. In this system, fluid is used as a working medium. When brakes are applied kinetic energy drives the pump to transfer fluid from low-pressure reservoir to high-pressure accumulator. During acceleration, fluid in high-pressure accumulator used to drive the motor which is connected to drive shaft of a vehicle.

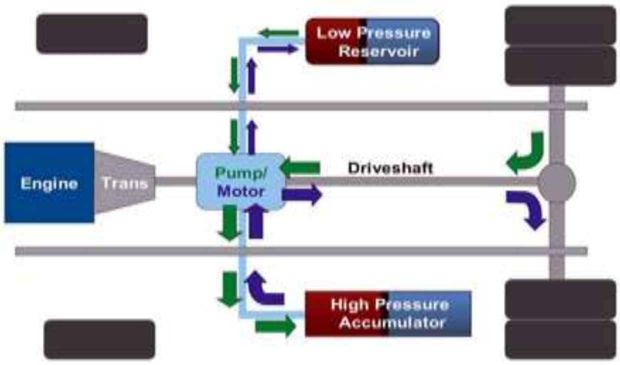

Figure 3: Schematic of Hydraulic RBS
(Source- http://energyeducation.ca/encyclopedia)

Figure 4 shows electric RBS. In this system, Kinetic energy is converted into electric energy with the help of generator store it in the battery. This electrical energy in Battery is used to drive the motor connected to the driveshaft.

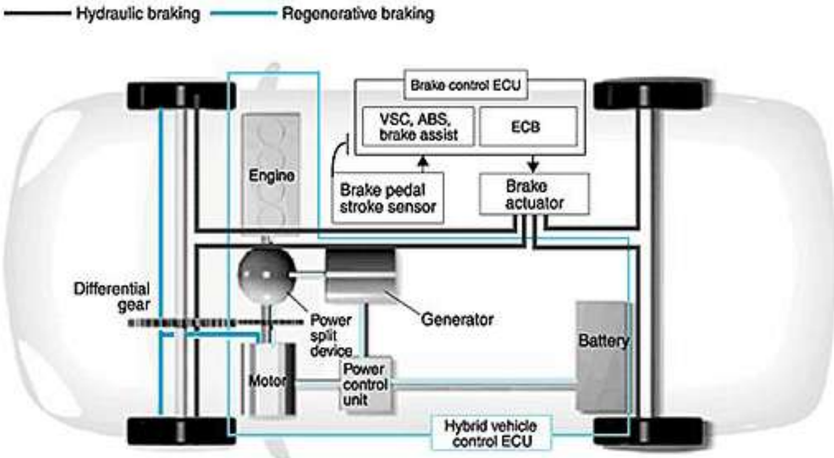

Figure 4: Electric Regenerative Braking System (RBS)
(Source: www.brighthub.com)

III. MODELLING AND SIMULATION OF RBS

MATLAB/Simulink Model:

In a thesis is presented by Brian Su-Ming Fan[5], MATLAB/Simulink and Advisor tools are used to generate the simulation architecture. Comparison of vehicle speed in both models is given in paper in which, there is close match between results[5]. Figure 5 shows overall model structure in MATLAB/Simulink. Also the data blocks of following model presented in details. The model components are setup in chronological order of data flow starting from left with drive cycle data and ending to right with ADAMS model subsystem[5].

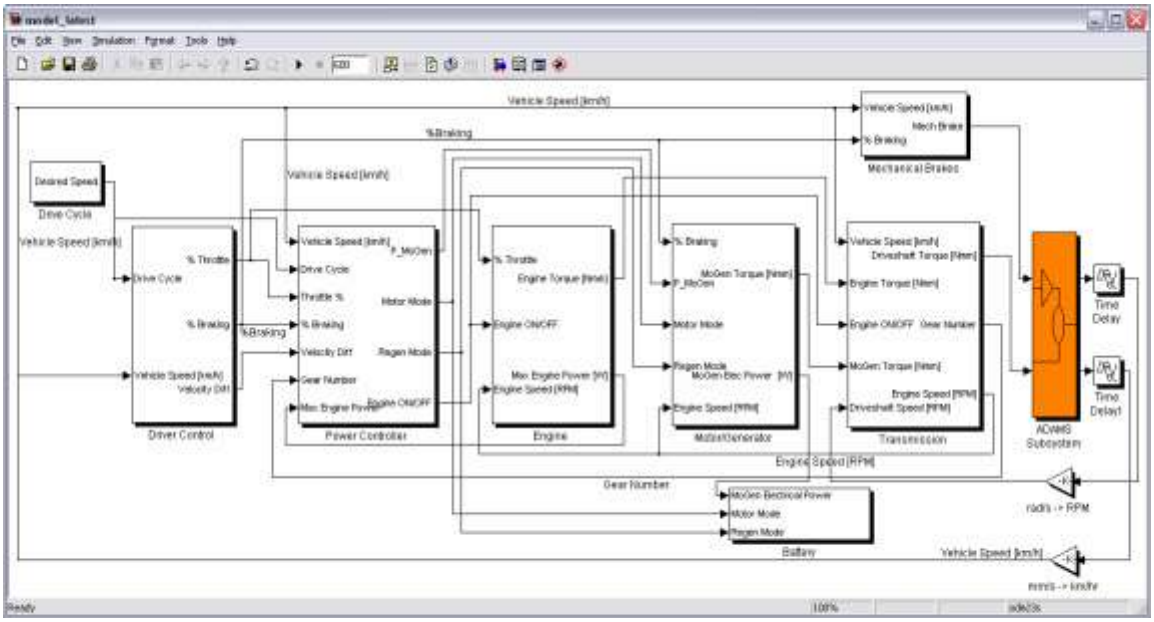

Figure 5. MATLAB/Simulink model of overall structure[5]

Results obtained are as follows:

I. New York City Cycle (NYCC) is used to simulate city driving[5]. The graphs are obtained from which comparison between conventional vehicle and hybrid vehicle model is summarised. Table 2 shows the results of simulation.

Vehicle model	Fuel Consumption	Distance Travelled	Fuel Economy
Conventional	0.1361	1.89	7.20
Hybrid	0.1246	1.89	6.56
% Difference	-8.92		-8.92

Table 2. results of simulation by NYCC [5]

From table it is found that the HEV model demonstrated 8.92% fuel economy improvement over conventional vehicle[5].

II. Highway Fuel Economy Cycle (HWFET) is used to simulate highway driving[5]. Table 3 shows the simulation result using HWFET.

Vehicle model	Fuel Consumption	Distance Travelled	Fuel Economy
Conventional	0.4423	16.45	2.69
Hybrid	0.3792	16.45	2.31
% Difference	-14.27		-14.27

Table 3. results of simulation by HWFET [5]

From table it is found that the HEV model demonstrated 14.27% fuel economy improvement over conventional vehicle[5].

GT-Suite Model:

In paper presented by M. Sh. Asfoor, A. M. Sharaf, and S. Beyerlein[8] GT-Suite tool is used for comparison between IC engine only (Conventional) vehicle and HEV with same engine.

Conventional Model: Figure 6 shows Conventional Vehicle model developed on GT-Suite. In this model ICE controller is used to simulate engine control functions such as idling and fuel cut off, Transmission controller and lockup clutch used to control gear selection and action of friction clutch respectively[8]. A environment module used to control air conditions that affect aerodynamic force on vehicle, A Road model is used to specify the road properties such as road grade, elevation, curvature radius and rolling resistance[8].

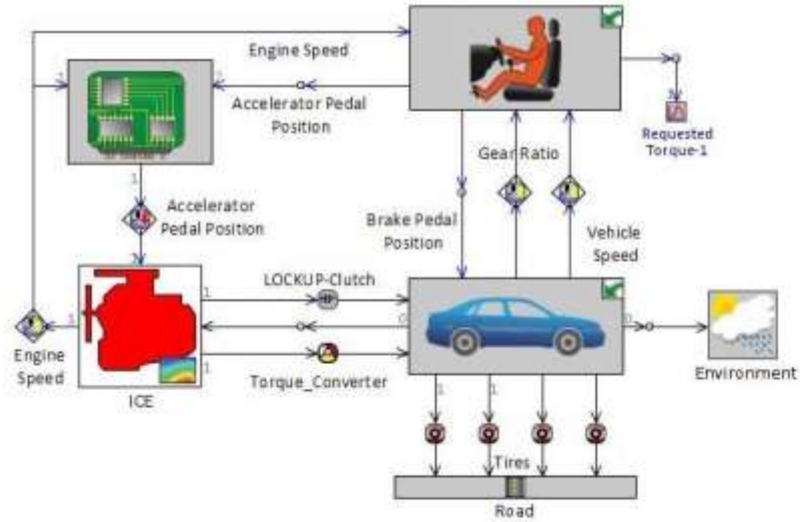

Figure 6. Conventional power planet model[8]

HEV models: In HEV two basic models are studied that are generated by adding typical components like motor, generator battery. Improvements in fuel economy and emissions are depends on supervisory control strategy it determines the power distribution between primary source (engine) and secondary source (battery)[9]. The battery model calculates the state of charge (SOC) which is the level of electric capacity in battery[8]. Braking module is used to calculate brake pedal position based on braking power and maximum torque capability of brakes and EMS is used to coordinate power flow between energy carriers[8]. Figure 7 shows the series HEV model developed in GT-suite. When battery state of charge above 0.7, the ICE is shutoff and when it decreases below 0.5, the ICE turned back on to charge the battery.

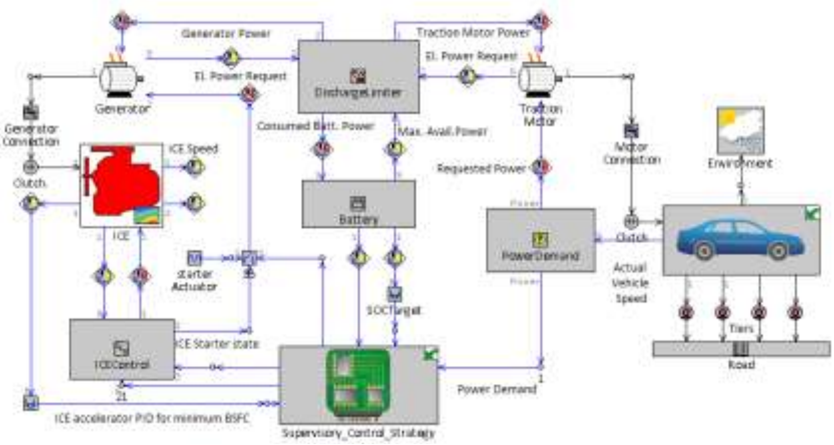

Figure 7. Series HEV planet model[8]

Figure 8 shows the parallel HEV model developed in GT-suite. The control system setup such a way that, when vehicle stops, the engine also shutoff. When it begins to move motor power the driveline which cranks the engine[8].

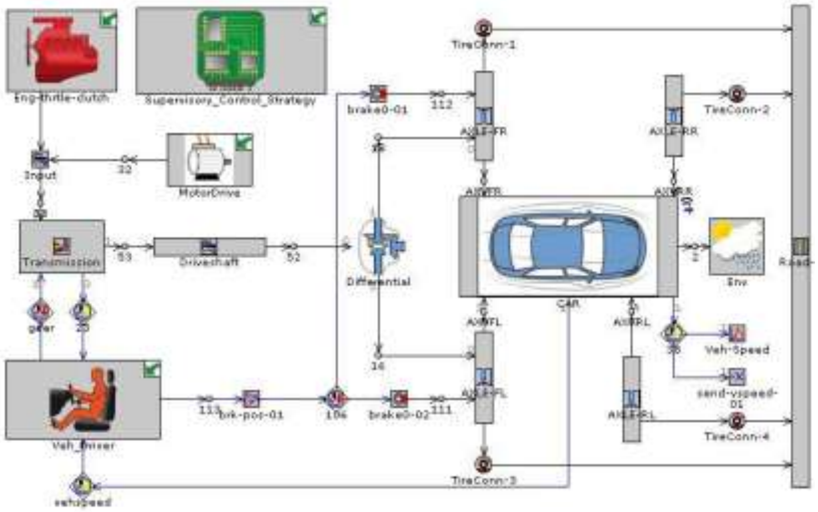

Figure 8. Parallel HEV planet model[8]

Four driving cycles are used to compare fuel economy of vehicle. Results obtained as shown in figure 9. Fuel economy for conventional vehicle is low as compared to both HEV models for all driving cycles. Series HEV gives maximum fuel economy NEDC driving cycle and parallel HEV gives maximum fuel economy for HWY driving cycle.

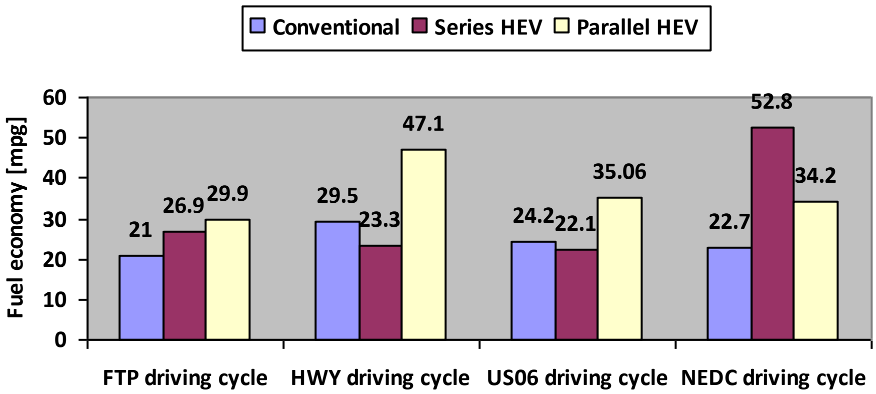

Figure 9. Fuel economy of different powertrain models[8]

IV. Conclusion

In this paper, comparison between Conventional Vehicle model and Hybrid Electric Vehicle model with Regenerative Braking Strategy, developed in MATLAB/Simulink and GT-Suite simulation tool is studied. Which shows that, HEV has better fuel economy than conventional vehicle. Regenerative braking strategy already used in many HEV's. Regenerative braking systems are particularly suitable in developing countries where heavy vehicles like truck and buses are most used for transportation within the cities. By reducing the complexity, increase in rate of production the cost of this system will reduce and it becomes more attractive than conventional vehicle.

References

[1] M.K Yoong, Y.H Gan, G.D Gan, C.K Leong, Z.Y Phuan, B.K Cheah. K.W Chew, Studies of Regenerative Braking in Electric Vehicle

[2] SONIYA.K. MALODE, R.H.ADWARE, REGENERATIVE BRAKING SYSTEM IN ELECTRIC VEHICLES, *International Research Journal of Engineering and Technology (IRJET) Volume: 03 Issue: 03*

[3] PULKIT GUPTA, ANCHAL KUMAR, SANDEEPAN DEB, 4SHAYAN, REGENERATIVE BRAKING SYSTEMS (RBS) (FUTURE OF BRAKING SYSTEMS), *International Journal of Mechanical and Production Engineering, Volume- 2, Issue- 5*

[4] John William Miller, Design of a Single Axle Regenerative Brake System for a 2005 Thru-the-Road Hybrid Electric Chevrolet Equinox, *Master's Thesis, University of Tennessee, 2006.*

[5] Brian Su-Ming Fan, Modeling and Simulation of a Hybrid Electric Vehicle Using MATLAB/Simulink and ADAMS, *University of Waterloo, Ontario, Canada, 2007*

[6] Massey, Sanjai, "MODELING, SIMULATION AND CONTROL OF HYBRID ELECTRIC VEHICLE DRIVE WHILE MINIMIZING ENERGY INPUT REQUIREMENTS USING OPTIMIZED GEAR RATIOS", *Open Access Master's Report, Michigan Technological University, 2016.*

[7] Ajinkya Gore, S.B. Sanap, R. V. Mulik, Design of Regenerative Braking Control Strategy for Parallel Hybrid Vehicle, *International Engineering Research Journal Page No 140-143*

[8] M. Sh. Asfoor, A. M. Sharaf, and S. Beyerlein, USE OF GT-SUITE TO STUDY PERFORMANCE DIFFERENCES BETWEEN INTERNAL COMBUSTION ENGINE (ICE) AND HYBRID ELECTRIC VEHICLE (HEV) POWERTRAINS, *Proceedings of the 16 th Int. AMME Conference, 27-29 May, 2014*

[9] Jianping Gao, Fengchun Sun, Hongwen He, Guoming G. Zhu, Elias G. Strangas, A Comparative Study of Supervisory Control Strategies for a Series Hybrid Electric Vehicle, *IEEE*

[10] A Vamsi Krishna, G Suraj Kumar, Ashish Kumar, M Sampath Kumar, Singaiah Gali, Hybrid bike, *International Journal & Magazine of Engineering, Technology, Management and Research, ISSN No: 2348-4845*