Chapter 9
Review on Regenerative Braking System

A. Sathishkumar, R. Soundararajan, T. J. Muthu Vel, M. B. S. Arjith, and G. Sakthivel

1 Introduction

Deceleration is the most important subsystem of an automobile in the safety aspect. The application of the brakes in the moving vehicle is to diminish the speed or to stop the vehicle's movement. This can be achieved by applying the force on the brake pedal. While applying the force on the brake pedals, the vehicle comes to rest at a particular distance which is defined as the braking distance. When the brake pedal is applied, dynamic energy is changed into heat energy in the commercially used braking system. This heat is formed due to the generation of friction between the brake drum and friction pad. There is a wastage of energy because the heat formed is moved away in the air stream. The loss of total energy through this process is depending upon the following factors, (a) how often the brakes are applied, (b) how hard the brakes are applied and (c) how long the brakes are applied [1]. The development of electric vehicles in the automobile sector has gotten consideration from the legislature and the industries. The government and the industries are focused on the development of electric vehicles due to global warming and the fossil fuel shortage. The performance of electric vehicle in various aspects such as driving range, powertrain efficiency, safety and energy-saving is low when compared with conventional vehicles [2]. Regenerative Braking System (RBS) is the developing braking system in hybrid electric vehicle (HEV) as well as in ordinary electric vehicle (EV), where it reduces the heat loss formed while applying the conventional braking system. In a traditional braking system, when the brake pedals are pressed the brake drum gets attached to the friction pads. The dynamic energy is lost as heat to the surroundings because of the friction between the brake drum and friction pad and the vehicle stops. The heat loss due to this system will be minimised by using the regenerative braking system (RBS). In RBS, the dynamic energy is

A. Sathishkumar · R. Soundararajan (✉) · T. J. M. Vel · M. B. S. Arjith · G. Sakthivel
Sri Krishna College of Engineering and Technology, Coimbatore, Tamil Nadu, India

M. Kathiresh et al. (eds.), *E-Mobility*, EAI/Springer Innovations in Communication and Computing, https://doi.org/10.1007/978-3-030-85424-9_9

converted into electrical energy and is stored in the electric vehicle's battery. The driving range and the fuel economy are improved in the electric vehicle which is incorporated with regenerative braking. A mechanical braking system (MBS) is still needed in order to stop automobiles during an emergency. In case of emergency, RBS didn't stop the automobile quickly as done by the commercially used braking mechanism. The MBS and the RBS can function in a same solitary foot pedal. The initial segment controls the RBS to diminish the vehicle's speed and the MBS is controlled by the final segment of the foot pedal to stop the vehicle immediately [3].

The minimal energy loss in the RBS describes the necessity of this braking mechanism in the electric vehicle domain. In addition to that, it also converts the kinetic vitality into electrical vitality and deposited it in the power saving unit. Thus, the RBS increases the functioning characteristics of the EVs. There are various parameters that can be changed to use this system effectively. Various researches have been done in this particular domain for using this braking system in a better way. The electric motor, control system and batteries used are the few parameters in the electric vehicles which influence the performance of this braking system.

2 Principle of Regenerative Braking

The regenerative braking mechanism operates based upon the electric motor's working principle. An electric motor is one of the major components of the electric vehicle. An electric motor rotates when the passage of moving charge is subjected to the coil. Similarly, when the rotor is actuated with the negative torque while applying the brake, the electric motor behaves as a power-producing device and generates electrical vitality. Thus, when the motor rotates in a particular direction it transforms the electrical vitality into mechanical vitality and maximises the acceleration of the automobile. When the electric motor rotates in the converse way, it acts like a power generating machine and generates electricity, which is stored in the batteries. Figure 9.1 represents the functioning arrangement of the regenerative braking mechanism [1].

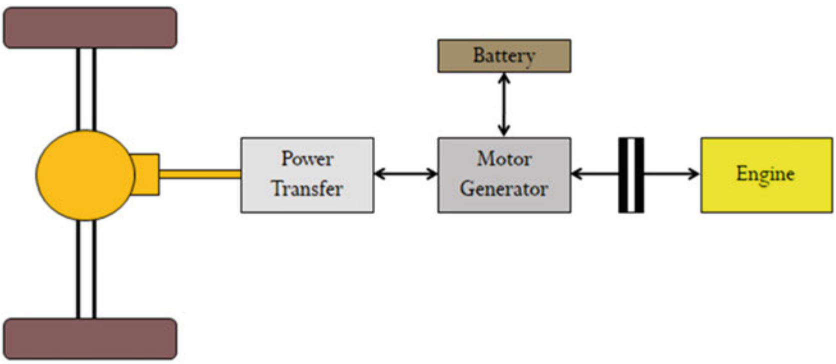

Fig. 9.1 Simple representation of regenerative braking

3 Research Findings on the Regenerative Braking System

A novel approach of a combined braking control strategy (CBCS) was proposed in this research work. This strategy is depending upon another technique of HEV braking torque conveyance, which operates the hydraulic braking mechanism simultaneously with the RBS. In the current study, a non-linear model of a vehicle which has a non-consistent and partly observational prototype of a tire with 5 degrees of freedom is made for the simulation. The simulation is done using MATLAB/Simulink. Functions of the various systems such as (a) anti-lock braking system, (b) controlling system, (c) system that controls the motor and (d) the units that manage the battery is examined in the simulation system to ensure the long-term performance of braking and regeneration vitality. The CBCS is the combination of two major control strategies such as (a) logic threshold control and (b) fuzzy logic control to secure the long-term braking characteristics of the vehicle. This strategy shields the wheel from being fastened and it regenerates maximum energy adequately. The fuzzy logic computations and the de-fuzzy recognition can be executed by the Mamdani technique and gravity centre technique in this current work by the researcher.

There are two classified parts of braking control design are proposed by the researcher in this present work. The first part is the logic threshold control strategy. This control technique is used for controlling the braking torque of the commercially used system of braking. The hydraulic braking torque of the conventional braking mechanism is adjusted in order to control the braking pressure as increasing, reserving and decreasing. The next technique is fuzzy logic control strategy and the block diagram of the fuzzy logic controller is represented in Fig. 9.2. By utilising the fuzzy logic control technique, the torque generated by the RBS is adjusted corresponding to the target slip ratio. The regenerative braking efficiency is simulated under new European driving cycle. While applying the conventional braking at the time of emergency on the roadways with a low sticking coefficient, its safety is also simulated. The hydraulic system of braking and the regenerative system of braking are worked together with the help of the proposed control strategies. They are worked together to ensure better braking performance and maximum regenerative efficiency, even on roadways having low-bond coefficient when emergency braking is needed [3].

By using the electro-mechanical brake, the researcher investigated the RBS of an electric vehicle in this research. The current innovations in braking technologies are progressed towards the brake-by-wire systems. In order to increase the consumption of fuel by EVs and their safety, the evolution of the electro-mechanical braking (EMB) system will also be a significant one. Figure 9.3 provides the systematic representation of various components and working of the regenerative braking systems in hybrid electric vehicles. The proposed system has an internal combustion engine with 1.4 L of capacity and an electric motor of 24-kW power. These are fastened to one of the axes of the HEV. The torque of the RBS and the EMB system is provided by the vehicle controller based on the following factors: (a) vehicle

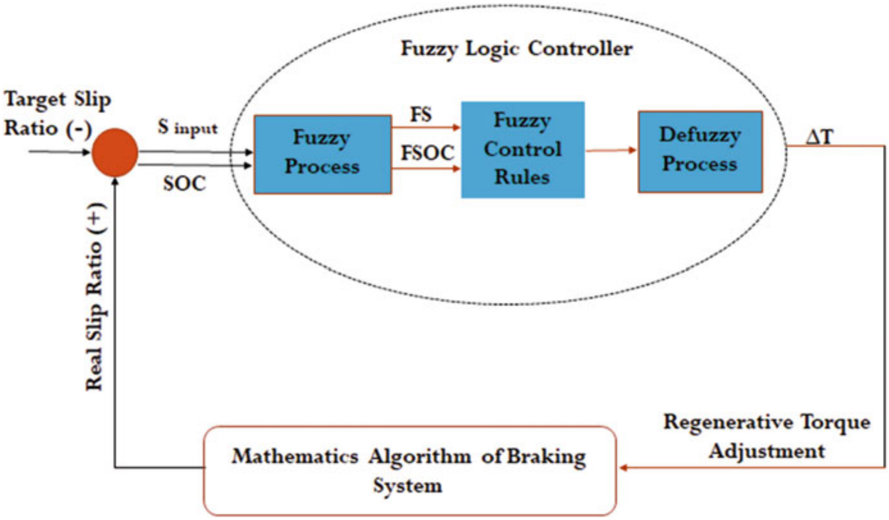

Fig. 9.2 Representation of the fuzzy logic controller using block diagram

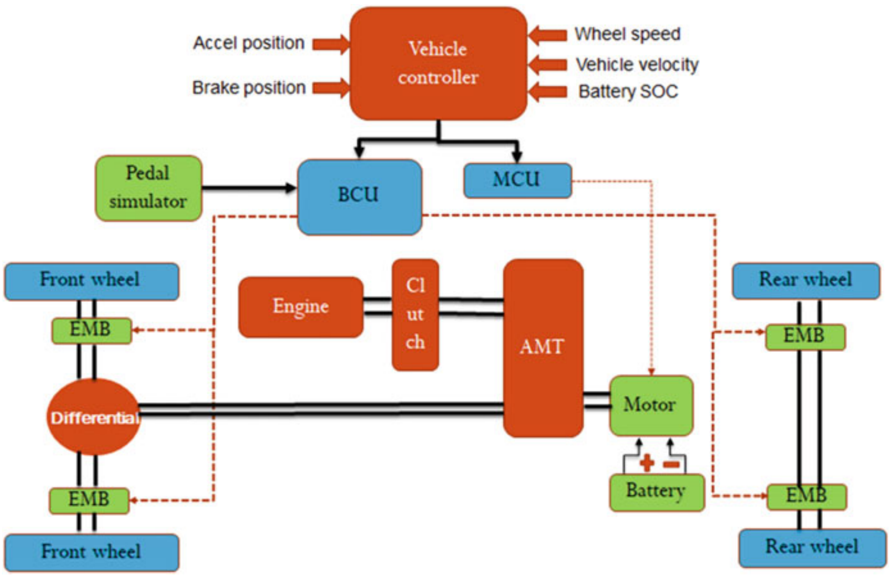

Fig. 9.3 Representation of braking control system in HEV

velocity, (b) battery's state of charge (SOC), (c) driver input and (d) motor characteristics. Based on the demand of the driver, the regenerative braking is working in accordance with the algorithm proposed. The regenerative braking's working is corresponding to the SOC of the battery. This phenomenon helps to increase the life of the battery. When the SOC value is more than 80%, the proposed algorithm does not allow the regenerative braking to work. The performance simulation of RBS in the HEV can be analysed using MATLAB/Simulink in the dynamic model. During different driving conditions, the control performance of the EMB system can be assessed using the simulation of the RBS incorporated in HEV. The outcomes from the simulation show that the proposed HEV which was furnished with an EMB system can regenerate more braking vitality. This can be achieved by utilising the control algorithm which was proposed [4].

A new design of the regenerative braking model is proposed mainly for a parallel HEV in this research work. This new model figures the pressure in the line and pad for the fore and back brakes. It also determines the usage of the generator based on the state of deceleration. This proposed model also has an algorithm, which avoided the wheels from lock-up. The development of a regenerative braking model involves the combination of different types of engines, batteries and electric motors. The product thus formed by the combination of three parameters is then simulated by the Advanced Vehicle Simulator (ADVISOR). ADVISOR is a type of simulator which is based on MATLAB/SIMULINK. This is also a feedback ward simulation especially for the simulations in HEV powertrains. The various parameters such as (a) performance, (b) emissions and (c) the fuel economy can be analysed quickly by using this simulator. The advanced driving schedule of the Federal Urban Driving Schedule (FUDS) is used in this research. The researcher took three types of engines, motors and batteries with various specifications. The displacement, power, maximum torque, mass and efficiency of the three engines differ from each other. Similarly, the power, maximum torque, maximum current, minimum voltage and efficiency of the three electric motors differ from each other. Three different batteries with different capacities, voltages and mass were used in this paper. The various behaviours such as (a) SOC of battery, (b) fuel economy along with (c) emission characteristics are compared with the baseline values and the proposed strategy of RBS [5].

The methodology to find the contribution made by RBS in the improvement of energy efficiency of the electric vehicle was proposed in this work. A pure electric passenger car is used for this research. A synchronous motor with a permanent magnet is acted as a motor and generator. By considering the regenerated braking energy, the energy stream of the electric vehicle was analysed. At the time of propulsion, the battery provides the required energy to all the electronic accessories. The regenerative energy is supplied to the electronic accessories when the regenerative braking is working.

The remaining regenerative energy is stored in the power-saving unit of the electric vehicle. The flow of energy in the electric vehicle in the presence and absence of regenerative braking is schematically represented in Fig. 9.4. The improvement in the efficiency of the electric vehicle by the regenerative braking system can be analysed by conducting three types of experiments with various control strategies. The non-regenerative braking test is the first experiment. The second experiment is carried with parallel regenerative braking strategies and the third experiment is done with serial regenerative braking strategies. Once the experiments are done, the methodologies for analysing the contribution made by

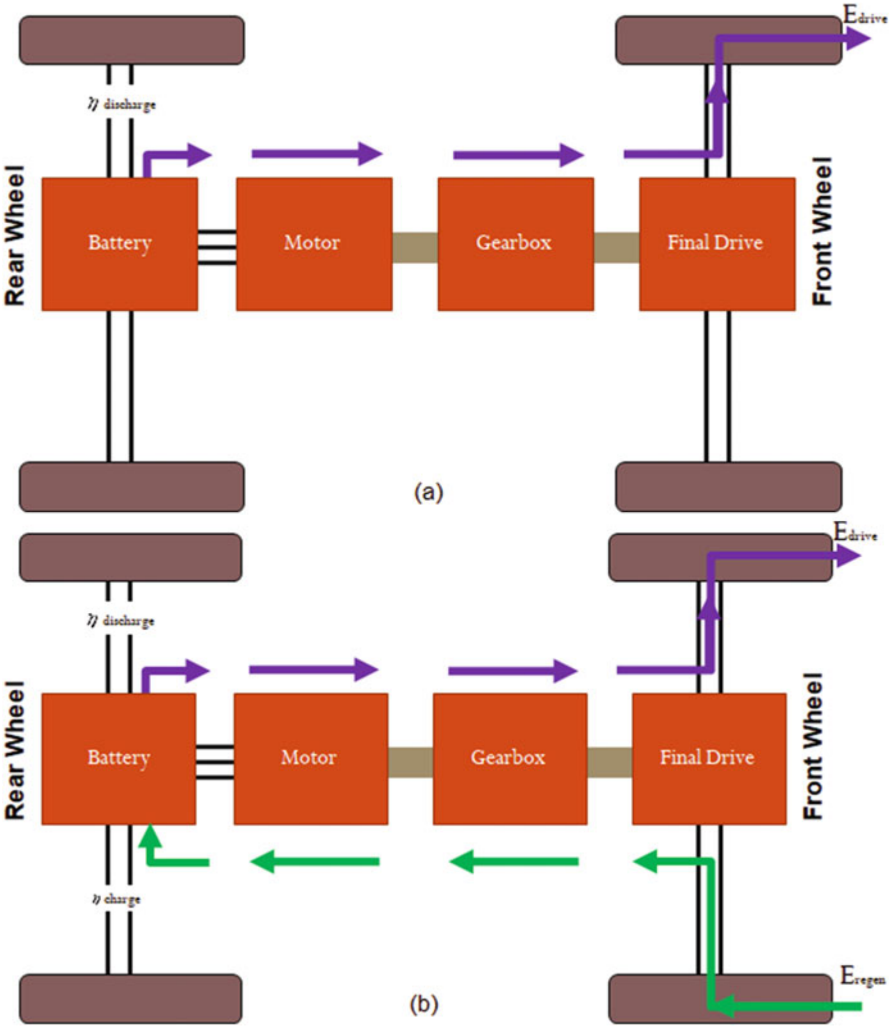

Fig. 9.4 Simple representation of energy flow in the vehicle with the presence and absence of regenerative braking

regenerative braking in the energy proficiency improvement in the vehicle were established. By using three diverse control strategies and standard driving cycles, various tests are done on the proposed vehicle on the chassis dynamometer. The results from the experiments showed that there is an increase of 11.18% and 12.58% of contribution ratios between energy efficiency improvement and extension in driving range made by the regenerative braking. These experimental results were obtained under New European driving cycles [6].

By using the vitality flow, the improvement in the energy efficiency by regenerative braking in the electric vehicle was analysed with the new mechanism in this research work. Novel methodologies are suggested for analysing the vitality contribution made by the RBS. An ordinary passenger electric vehicle is taken for the experimental investigations. In the practical implementation, the input and output power in the wheels are measured using the sensors. The researcher proposed two parameters for the vitality contribution analysis. The first parameter is to analyse the ratio between the vitality contribution and the driving range of the RBS. The next parameter is to analyse the ratio between the vitality contribution and transfer efficiency of the energy produced by RBS while braking is applied. To study the further efficiency enhancement, the author carried out a vehicle test on-road according to China Typical City Regenerative Driving Cycle. The new European drive cycle is adopted for analysing the improvement in the consumption of energy. The researcher proposed three strategies with different modifications on each to analyse the enhancement in the efficiency of the RBS. The author introduced 'serial 2 control strategy' as a new control strategy in regenerative braking. The researcher analysed two parameters based on vitality efficiency. One of the parameters is to analyse the vitality ratio of contribution to the driving range of the regenerative braking. The other one is to analyse the vitality ratio of contribution to improvement in the vitality transfer efficiency. On comparing the regeneration efficiency, the results exhibited that the vehicle with 'serial 2 control strategy' gives maximum efficiency from RBS. The serial 1and parallel strategy offers a minimum efficiency when compared with the serial 2 control strategy. But, the installation of sensors and the modifications made in the brake to adopt this strategy is a very complicated and costlier one [7].

The effects of using the dynamic energy of electric vehicles during braking and regenerating the electric power to charge the vehicles were investigated in this research work. Regenerative braking is an efficient technology that enhances the vehicle's driving range. The conventional braking method leads to a waste of kinetic energy into enormous heat during braking. It gave rise to regenerative braking which is efficient and helps in saving energy and cost. The researcher has mainly focused on the influence of brake energy in the regeneration of electric power. When the brakes are applied to slow down the vehicle, the RBS functioned simultaneously. The main working principle is that, when the rotor rotates in one direction, it acts as a motor. When it rotates in the contrasting direction, it acts as a power-generating device. A brushless DC motor is considered to be a main component of the regenerative electric vehicle. The ultracapacitor is the core technology that produces higher life cycles of a vehicle and also from the Matlab simulation the author has confessed that regenerative braking can save the waste kinetic energy of vehicles up to 8–25%. Figure 9.5 represents the simulation model of regenerative braking developed in Matlab [8].

In this research work, the author proposed a structure of a hybrid vehicle that had a battery or a fuel cell and a permanent magnet DC (PMDC) motor in it and performances were analysed by the researcher. The proposed hybrid vehicle model with various features is diagrammatically represented in Fig. 9.6. A clever controller is used in the hybrid vehicle structure that consists of a PMDC electric controller driven by a fuel cell/battery. This controller performs several tasks of regenerative

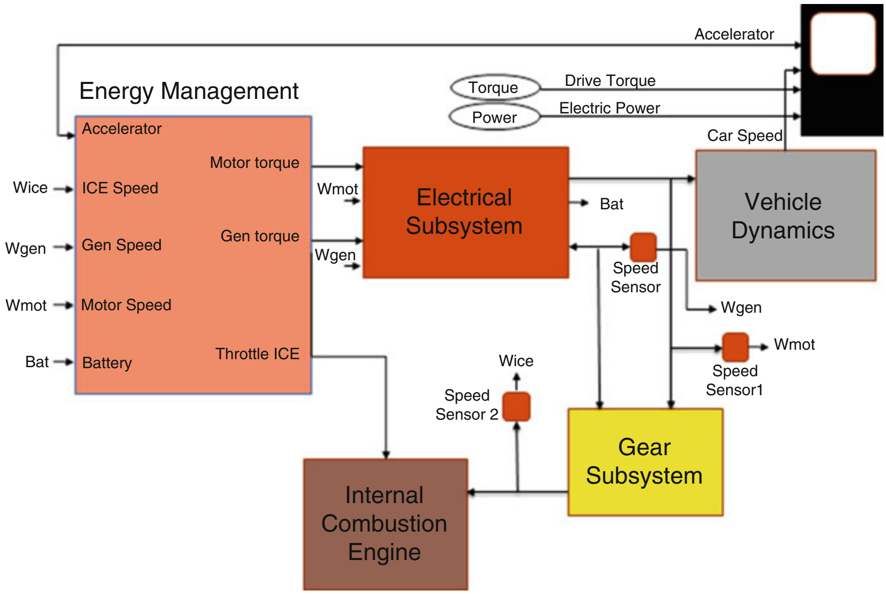

Fig. 9.5 Matlab simulation model of regenerative braking

braking & power management departments. With the help of switching strategy, the power of the fuel cell can be managed by DC to DC converter and the duty cycle is computed with the switching frequencies by a driving controller. Considering power demand, a neuro-fuzzy controller is implemented in order to consider power management issues. A simulation is done with respect to pedal displacement, battery state of charge act, a threshold zone for producing regenerative torque. The setup of the fuel cell and its components are available at the power system of the toolbox in MATLAB. Only longitudinal dynamics are considered in this simulation. By the simulation results, when the acceleration is given around 0–25 km/h, the fuel cell operates in the nominal amount of power and allows the battery to be charged. When the power requested by the driver exceeds the capacity of the fuel cell, the battery is triggered and both the fuel cell and the battery begin delivering the energy. From the regenerative braking test, the results conclude that the mechanical braking torque obtained is better than in the non-regenerative state. The results have clearly shown that when the vehicle is run in the uphill stream, the demand for power is past the ostensible volume of the fuel cell only; the battery ought to go into work with respect to have a commitment on power supplying [9].

An effective control system for regenerative braking is proposed by the researcher in this current investigation. HEVs are designed dependent upon suitable modification on a traditional hydraulic braking system furnished with an antilock braking system (ABS). To resolve limitation and pressure complications, a pressure coordinated control system (PCCS) is applied. The system model has been implemented in the simulation software. Assuming the opening perspectives of the high-speed

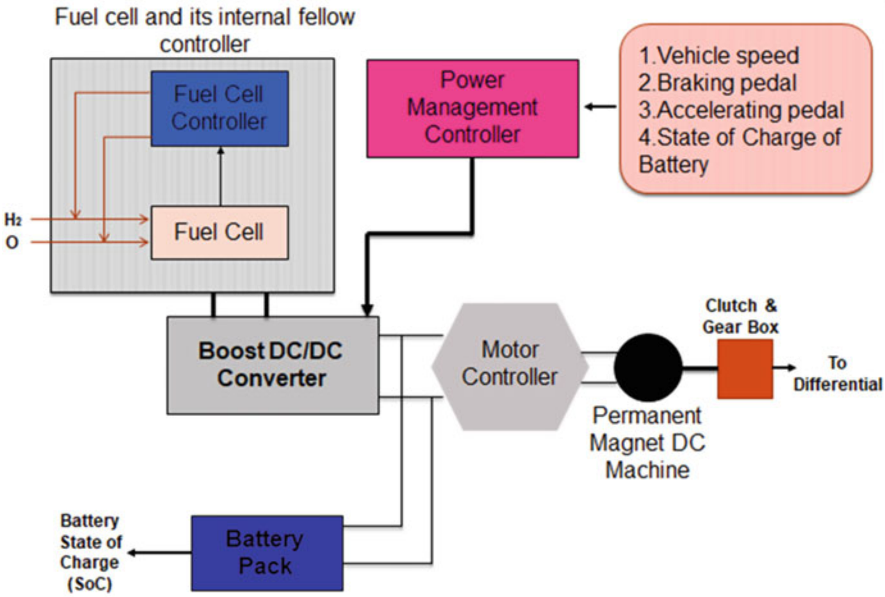

Fig. 9.6 Diagrammatic representation of the proposed hybrid vehicle

switching valve, to look after the booster valve and reducing the valve's duty cycle, a PID-bang bang controller is utilised in this study. At typical driving cycles, the forces obtained through braking not only satisfy the required braking of a vehicle but also increase regenerative braking efficiency by 12.5%. For the parallel braking approach, a minimal amount of energy has been recovered since its design has a simple structure. A control method called Pulse Width Modulation (PWM), utilised by PCCS, insisting a quicker reaction of braking force and it holds appreciable real-time tracking performance. In respect to PCCS, the wheel velocity precisely tracks the slip ratio, braking distance by the wheel & force by braking. If the distance of braking is at 50 m, the slip ratio differs lightly almost at the anticipated rate of 0.2, at the same time braking force changes in the ABS process. Thus, it indicates that the PCCS accomplishes a substantial performance of ABS [10].

For an automatic transmission (AT) based HEV, a brake system has been created and accompanied by a regenerative braking cooperative control algorithm. An electronic hydraulic brake (EHB) has setup on the rear wheels that are also used in friction brake system (FBS), so that the system need not expect a pedal simulator, and an electronic wedge brake is used on the vehicle's front wheels as represented in Fig. 9.7. A regenerative braking cooperative control algorithm is determined based on the model of FBS. Using the dynamic model of the braking system, this algorithm is made to distribute friction force and regenerative braking force. A simulator is developed based on this algorithm and the results are taken based on the simulation. From the result, it has attained the demanded braking force and based on its gradient with respect to pedal stroke, the energy is recovered. Assuming that gradient

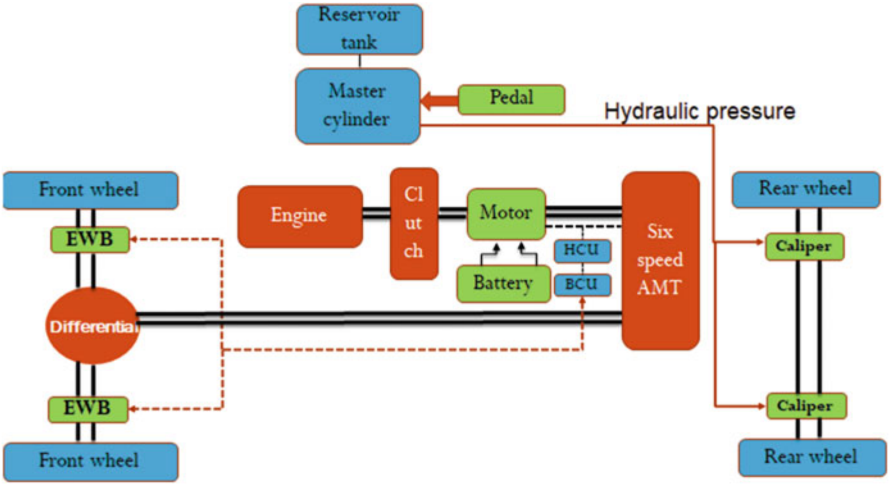

Fig. 9.7 Structure of the brake system

obtained with respect to total demanded braking force increases with respect to the pedal stroke, the braking force obtained due to friction at the rear wheel becomes lesser, additional force is provided due to extra braking that is transferred to the front wheels and thus there is an increase in the recovery of energy at regenerative braking [11].

This proposed research study develops a unique integrated brake pressure control algorithm based on two high-speed on–off valves to ensure precise and timely pressure monitoring for the regenerative braking system adopted in electric commercial vehicles. Two distinct models are being used in this study, first type is a valve control system made based on the mathematical model that is comprised of various sub-models. In another type, A PID Controller combining a fuzzy controller with pulse width modulation (PWM) is acquired separately with the incorporated algorithm to fill in with the traditional PWM approach. The tracking of the pressure of air cylinder is done and also the behaviour of 2/2 high-speed valve is read and with the help of thermodynamic and mechanical property of filling and depletion process of airflow is done periodically. With the results obtained from the simulation in PID Controller, a pressure response is obtained and they are capable to meet the target with respect to the response obtained in experimental results. From the results, it is concluded that the brake safety and brake feelings are improved significantly [12].

A method named dynamic low-speed cut-off point detection that is to be combined with EV is proposed in this research. In this type, one doesn't need to alter the hardware and the architecture of vehicle braking and can be applied exclusively by altering the brake controller. A strategy has been developed to control the diffusion of brake force in EV between RBS and FBS which depends on fuzzy logic control. Some factors like deceleration rate, mass at the vehicle, speed of the wind and slope angle with respect to the road were analysed individually in a simulation model based on the displacement of breaking cut-off point.

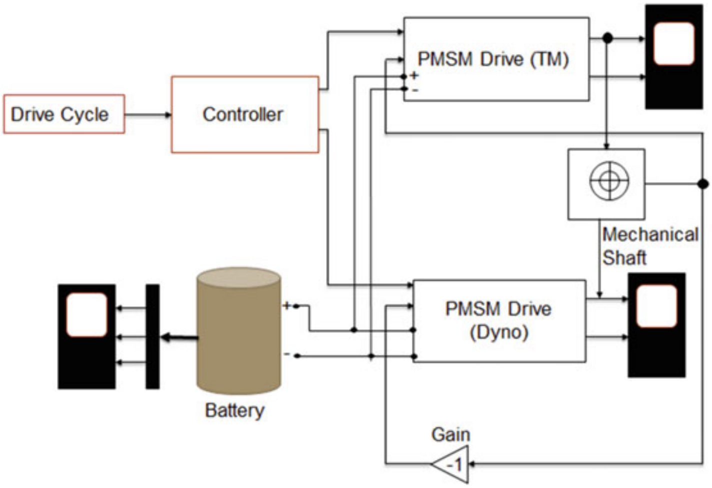

Fig. 9.8 Simulation model diagram

Figure 9.8 represents the proposed EV simulation model. From the simulation results, it is understood that if a deceleration rate is faster or when the vehicle mass is high, it increases the low-speed cut-off point (LSCP) while an increase in speed of the wind and in the uphill driving it ends up in LSCP. With the brake controller considering dynamic LSCP shows that, designing a brake controller with the change of state of LSCP, the loss of energy during RBS can be reduced or avoided and can enhance the driving range of the vehicle. The experimental results tell us that by grabbing the advantage of the proposed method, the energy recovery in RBS can be enhanced greatly assuming that having a constant low-speed threshold during the process of braking [13].

A brake controller which is almost similar to the actual EV brake system is added to its design with the consideration of limitations in both RBS and FBS. The designed brake controller is coordinated into the controller of the EV hardware-in-loop (HIL) test bench. With the help of the advanced vehicle simulator, several results of experimented HIL energy consumption are obtained and investigation of consequences on adding a brake model is also done. The two main limitations are considered while integrating EV braking and determining the share of regenerative braking. The limitation that is considered first is the capability of RBS to maximise the recovery of energy. This is considered as a major factor as it can affect energy recovery in RBS a lot during harsh deceleration.

The second limitation is efficiency contemplation and also the consumption of energy is the reason why the electric motor doesn't function as a generator that regenerates the battery of a vehicle at low energy consumption. One of the main elements is the controller that controls the drive motor and dynamometer under various circumstances. It is capable of calculating the speed reference with respect to drive motor and resistive torque reference with respect to the dynamometer. The drive motor used is a 15kw Six Pole Permanent Magnet Synchronous motor

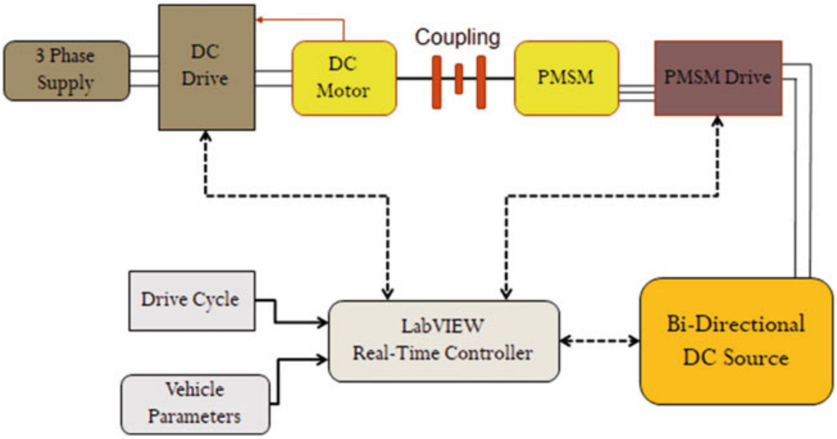

Fig. 9.9 Experimental setup

(PMSM) and the experimental setup for the proposed model of brake controller is presented in Fig. 9.9. The result shows a realistic approach towards braking limitations with respect to EV emulation on motor/dynamometer model & almost gives an exact assessment of the performance of an EV [14].

An electromagnetic brake designed as a miniature that is similar to conventional brake structure, designed with a 3D map, called capacitance and rotating speed module map, comprising of capacitance, the rotating speed and stator resistance, can predict whether the self-excitation occurs which results in the feasibility of the designed process. Electromagnetic brakes are also used in heavy vehicles along with the usual friction brakes. Effect of four influenced parameters namely magnetising inductance, resistance in the rotor, leakage inductance in the stator and also leakage inductance in rotor have been studied with an electromagnetic regenerative braking system. Using the finite element analysis, one can determine the magnetising inductance and leakage inductance. Avoiding hysteresis loss, the actual shaft torque will be smaller with respect to actual air gap torque. Then the voltage and current are being obtained with the help of the LeCroy Oscilloscope. The experiment results provide the value, that is almost equal to the 3D analysis and hence the minimal loss is caused provided that it is due to hysteresis loss. The Capacitance Map greatly helps to determine whether self-excitation happens or not in an electromagnetic regenerative braking system for several speed and capacitance [15].

The updated model of a novel electro-hydraulic brake system named Regenerative electro-hydraulic brake (REHB) is proposed in this research work. Simulators dealing with stroke are recommended to increase the pedal feel quality. The researcher coordinates the regenerative braking with hydraulic braking. In order to combine these two, the pressure containing in the master cylinder should not be equal to pressure containing in the wheel cylinder. This method can be attained only by brake-by-wire feature. To achieve this method, a solution based on high-pressure accumulator and a solution based on an electric booster is utilised. To ensure the highest amount of force due to regenerative braking, brake force due to friction should be linked which can be done by designing a blending control strategy for the braking force. The performance of the proposed braking strategy was analysed by Hardware In Loop bench test (HIL). Keeping fundamental control in mind, to obtain better precision of hydraulic pressure modulation and to eradicate noise caused due to vibration, a method called current amplitude modulation is adopted. With the help of the MATLAB-AMESism co-simulation platform, a model is constructed for high fealty models of vehicle and brake systems. From the analysis it is concluded that REHB with a very straightforward structure, improves the regenerative brake by wire system execution when compared to EABS and iBooster generation [16].

To carry on solidity and to refine the regenerative braking during unpredictable weak situations, a knowledge-based structure is designed which is called as a hierarchical control structure. The energy recovery analysis was also made in this research work. The researcher revealed that battery capacity is one of the major aspects that influence braking efficiency. The wheel-braking force which is made by braking actuators and the braking force generated by the tire-road interaction were analysed. The author also made a comparison on the simulation of the braking on high adhesion roads and on the slippery road. While reaching the optimum anti-skid braking performance, this feature enormously assists to maintain a strategic distance to determine the optimum slip ratio. The outcome of this method provides that this feature stops the locking of the wheel and makes regenerative braking effective as it can retrieve kinetic energy as best as it can. To observe the efficacy, the experiment and simulation are executed. The setup and working flow of the hybrid braking system used in this research work are represented in Fig. 9.10 [17].

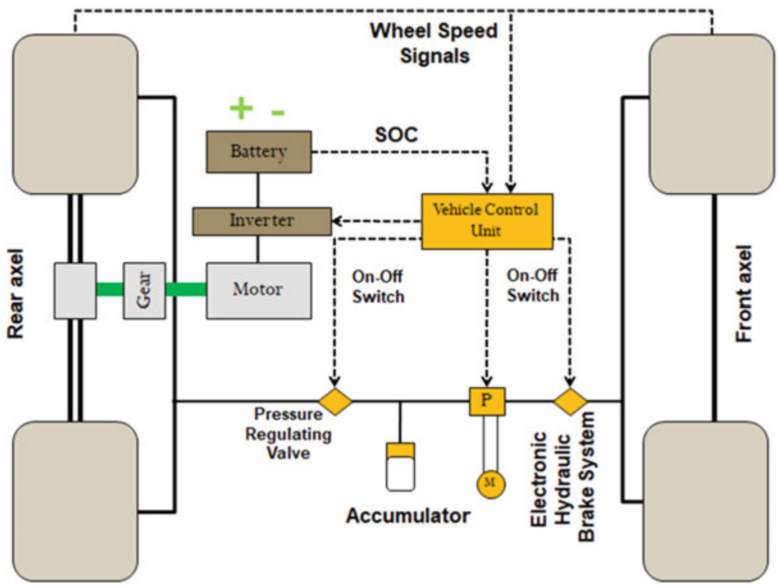

Fig. 9.10 Hybrid braking system

Creative RBS is adapted to brushless DC (BLDC) motor in the present study, which stresses on the conveyance of the force due to braking along with BLDC motor control. BLDC employs proportional-integral-derivative (PID) control during the distribution of braking force by utilising fuzzy logic control. At various brake pedal inputs, simulation analysis is done on dynamic performance and also with brake pedal distribution. Also, the researcher made the simulation on EV speed curve, energy recovery efficiency along with SoC (State of Charge). The researcher also adopts PID control to regulate the BLDC motor pulse width modulation duty in order to receive the same amount of brake torque. The combination of PID control and fuzzy control can make a smooth transient. Comparing with other solutions, the new one has shown finer conduct with respect to efficacy, robustness and realization [18].

4 Summary

- Combined braking control strategy (CBCS) operates the hydraulic braking system simultaneously together with the RBS, preventing the wheels from being fastened thereby effectively regenerates more energy.
- ADVISOR is a MATLAB/SIMULINK-based analyser is used for analysing (a) performance, (b) emissions and (c) fuel economy of the electric vehicle quickly.
- Regenerative braking to energy efficiency improvement and to driving range extension was up to 11.18% and 12.58%, respectively. Also, save the waste kinetic energy of a vehicle up to 8–25% and effectively regenerate the energy of braking by 12.5%.
- The parameters such as analysing the ratio between the vitality contributions to the driving range of the RBS and analysing the ratio between the vitality contributions to transfer efficiency of the regenerative braking is used primarily to analyse the vitality contribution made by regenerative braking.
- With the dynamic approach of the RBS cooperative control algorithm, it is made to distribute the friction and regenerative braking force which helps to recover energy based on the gradient flow with respect to the pedal stroke.

References

1. Patil, S. K. (2012). Regenerative braking system in automobiles. *International Journal of Research in Mechanical Engineering & Technology, 2*(2), 45–46.
2. Xu, G., Li, W., Xu, K., & Song, Z. (2011). An intelligent regenerative braking strategy for electric vehicles. *Energies, 4*, 1461–1477. https://doi.org/10.3390/en4091461
3. Peng, D., Zhang, Y., Yin, C. L., & Zhang, J. W. (2008). Combined control of a regenerative braking and antilock braking system for hybrid electric vehicles. *International Journal of Automotive Technology, 9*(6), 749–757. https://doi.org/10.1007/s12239-008-0089-3

4. Ahn, J. K., Jung, K. H., Kim, D. H., Jin, H. B., Kim, H. S., & Hwang, S. H. (2009). Analysis of a regenerative braking system for hybrid electric vehicles using an electro-mechanical brake. *International Journal of Automotive Technology, 10*(2), 229–234. https://doi.org/10.1007/s12239-009-0027-z
5. Panagiotidis, M., Delagrammatikas, G., & Assanis, D. (2000). Development and use of a regenerative braking model for a parallel hybrid electric vehicle. *SAE Technical Paper Series, 01*, 0995. https://doi.org/10.4271/2000-01-0995
6. Lv, C., Zhang, J., Li, Y., & Yuan, Y. (2015). Mechanism analysis and evaluation methodology of regenerative braking contribution to energy efficiency improvement of electrified vehicles. *Elsevier Energy Conversion and Management, 92*, 469–482. https://doi.org/10.1016/j.enconman.2014.12.092
7. Qiu, C., & Wanga, G. (2016). New evaluation methodology of regenerative braking contribution to energy efficiency improvement of electric vehicles. *Energy Conversion and Management, 119*, 389–398. https://doi.org/10.1016/j.enconman.2016.04.044
8. Malode, S. K., & Adware, R. H. (2016). Regenerative braking system in electric vehicles. *International Research Journal of Engineering and Technology (IRJET), 03*(03), 394–400.
9. Naderi, P., & Azizianfard, M. (2013). A fuel cell/battery hybrid vehicle modelling and power management/regenerative braking controller design. *Journal of Fuel Cell Science and Technology, 10*(011008), 1–12. https://doi.org/10.1115/1.4023384
10. Yang, Y., Zou, J., Yang, Y., & Qin, D. (2014). Design and simulation of pressure coordinated control system for hybrid vehicle regenerative braking system. *Journal of Dynamic Systems, Measurement, and Control, 136*(051019), 1–8. https://doi.org/10.1115/1.4027283
11. Ko, J., Ko, S., Son, H., Yoo, B., Cheon, J., & Kim, H. (2015). Development of brake system and regenerative braking cooperative control algorithm for automatic-transmission-based hybrid electric vehicles. *IEEE Transaction on Vehicular Technology, 64*(2), 431–440. https://doi.org/10.1109/TVT.2014.2325056
12. Pi, D., Cheng, Q., Xie, B., Wang, H., & Wang, X. (2019). A novel pneumatic brake pressure control algorithm for regenerative braking system of electric commercial trucks. *IEEE Access, 7*, 83,372–83,383. https://doi.org/10.1109/ACCESS.2019.2924739
13. Heydari, S., Fajri, P., Rasheduzzaman, M., & Sabzehgar, R. (2019). Maximizing regenerative braking energy recovery of electric vehicles through dynamic low-speed cut-off point detection. *IEEE Transactions on Transportation Electrification, 5*(1), 262–270. https://doi.org/10.1109/TTE.2019.2894942
14. Fajri, P., Lee, S., Prabhala, V. A. K., & Ferdowsi, M. (2016). Modelling and integration of electric vehicle regenerative and friction braking for motor/dynamometer test bench emulation. *IEEE Transaction on Vehicular Technology, 65*(6), 4264–4273. https://doi.org/10.1109/TVT.2015.2504363
15. Bae, J.-N., Kim, Y.-E., Son, Y.-W., Moon, H.-S., Yoo, C.-H., Jung, T.-C., Lee, J., Huh, K., & Jin, C.-S. (2014). Design and analysis of a regenerative electromagnetic brake. *IEEE Transactions on Magnetics, 50*(11), 8103204. https://doi.org/10.1109/TMAG.2014.2327621
16. Yuan, Y., Zhang, J., Li, Y., & Li, C. (2018). A novel regenerative electrohydraulic brake system: development and hardware-in-loop tests. *IEEE Transaction on Vehicular Technology, 67*(12), 11,440–11,452. https://doi.org/10.1109/TVT.2018.2872030
17. Xu, G., Xu, K., Zheng, C., Zhang, X., & Zahid, T. (2016). Fully electrified regenerative braking control for deep energy recovery and maintaining safety of electric vehicles. *IEEE Transactions on Vehicular Technology, 65*(3), 1186–1198. https://doi.org/10.1109/TVT.2015.2410694
18. Nian, X., Peng, F., & Zhang, H. (2014). Regenerative braking system of electric vehicle driven by brushless DC motor. *IEEE Transactions on Industrial Electronics, 61*(10), 5798–5808. https://doi.org/10.1109/TIE.2014.2300059