ISSN: 0974-5823 Vol. 7 No. 5 May, 2022

International Journal of Mechanical Engineering

Regenerative Braking System in Electric Vehicles using Induction Motor

Macha Mahija
M.Tech Student, Department of Electronics design and Technology
National Institute of Electronics and Information Technology Aurangabad, Maharashtra.
Prashant Pal
Scientist/Engineer 'B'
National Institute of Electronics and Information Technology Aurangabad, Maharashtra.

Abstract: New technologies are being developed to promote energy efficiency as the need for green energy grows. Regenerative braking is a way for increasing the efficiency of electric and hybrid vehicles by reducing the amount of energy they use. An induction-motor-driven electric vehicle (EV) is proposed in this research for regenerative braking (RBS) with a battery energy storage system (BESS). At this point, the motor is acting as a generator. Because of this, the DC-link voltage is increased and energy is transmitted to the battery by means of an inverter using a suitable switching strategy. You can use this power to boost acceleration and/or keep the battery pack from running low while driving on a hill. A PI controller adjusts the braking current to maintain consistent torque braking. We run a variety of simulations to gauge the proposed RBS's performance. The results show that the planned RBS has a high level of capability.

Key words: Regenerative Braking System (RBS), Battery Energy storage system (BESS), Electric Vehicle (EV), Induction motor (IM)

I. INTRODUCTION

Due to its unique attributes such as minimal emissions, high efficiency, and silent operation, electric and hybrid electric vehicles (HEVs) are garnering increasing interest. Traditional automobiles powered by internal combustion engines (ICEs) can be replaced with electric vehicles and hybrid electric vehicles (HEVs) in the era of green technology. As a result, they're helping to improve vehicle efficiency once again. On the other side, the prohibitive cost of EVs/HEVs has kept them off the road in large numbers. By simplifying EV settings, the goal of this project is to make it less cumbersome for users. One of the primary goals of research is to find a way to increase the amount of power that can be recovered through braking. Using this thesis' research, a control method for improving the vehicle's overall braking performance has been developed.

Because they offer an environmentally friendly alternative to vehicles powered by internal combustion engines, electric vehicles (EVs) are currently receiving a lot of attention. Hybrid and electric vehicle development is becoming increasingly popular. As a result, there has been an increase in the public's awareness of global warming and an increase in the cost of gasoline. Due to rising oil prices and an increase in air pollution, electric vehicles (EVs) have become the primary and final mode of transportation. In a battery-operated EV, the primary source of power is the battery, which is experiencing issues such as a lack of charging and recharging cycles as well as inadequate responsiveness in terms of driving range [2-5]. Ultra capacitors, flywheels, electrochemical batteries, and other energy sources can all be used to solve the challenges listed above [5-7].

Regenerative braking is one of several procedures that have been implemented to address this issue. Some of the vehicle's kinetic energy is stored during deceleration in the form of kinetic energy, which is translated and stored in the battery and ultracapacitor [7-10]. The regenerative braking does not work all the time on a smooth road surface. It can be seen in places where vehicles have to apply the brake, such as speed bumps, pits in the road, and slopes.

Only when the battery is fully charged can regenerative braking be noticed; otherwise, mechanical brakes is required in EVs. Electric vehicles employ mechanical brakes to enhance the roughness of the wheel in order to decelerate. Since the EV's kinetic energy is converted back into electric energy when the mechanical brake is applied, this wastes a significant amount of energy. Regeneration is possible with the simple-to-control motors. Mechanical brakes are typically utilised in two-wheel EVs to slow or stop the vehicle's speed; this results in the loss of all stored kinetic energy [11–15]. The kinetic energy lost during braking can be recovered and stored in batteries and ultra capacitors as electrical energy. If the motor, drive, and battery are all properly handled and controlled, this energy can be stored in the battery. To date, demand for electric vehicles has been expanding in response to the market.

II. LITERATURE SURVEY

There are numerous ways to increase the performance of hybrid energy storage systems, including design optimization and automation, according to the work of Y. Kim and N. Chang. Each strategy for storing energy has its own benefits and drawbacks, making it possible to construct a high-performance, low-cost battery using a hybrid approach that offers both. New design optimization methods and energy-efficient operation systems are introduced. In addition, a 300 W scale hybrid energy storage system prototype is described in detail by the author.

According to a study published in the journal Energy Storage Systems for Automotive Applications et. All [2], the fuel efficiency and performance of innovative cars with electric propulsion capabilities are greatly constrained by their capacity to store energy efficiently and effectively. [2] (ESS). The current state of ESSs in automotive applications is examined in this research. Battery technology choices are examined in great detail, with a focus on battery monitoring, management, protection, and balancing approaches. Additionally, ultracapacitors, flywheels, and fuel cells are mentioned as ESS options. Last but not least is the concept of merging two or more energy storage devices to generate a more powerful power source, known as hybrid power sources.

According to the classification and review of control strategies for plug-in hybrid electric vehicles by S. G. Wirasingha and A. Emadi, [3] In plug-in hybrid electric vehicles (PHEVs), selecting the right drive train architecture and implementing an effective power flow control method are both critical to reducing fuel consumption and emissions. Control techniques for hybrid electric vehicles (HEVs) have been devised and presented, however they do not take full use of the PHEV's ability to operate in electric-only mode over substantial distances. The most up-to-date control strategies are examined and organised in this work. While both rule-based and optimization-based PHEV control algorithms have their merits, they are not mutually exclusive. The controllers are described in detail, and an evaluation of the best technique for maximising PHEV performance under various driving circumstances is offered. Finally, a new classification of PHEV control strategies based on the vehicle's operation has been provided and proven by simulation results.

According to M. Montazeri and M. Soleymani in their study, "Investigation of the energy regeneration of the active suspension system in hybrid electric vehicles et. all.,"[4] hybrid electric vehicles' active suspension (AS) system can be used to generate power (HEVs). Simultaneous simulation and control methods are used to produce a unified medium in which both HEV powertrain and AS systems are simulated simultaneously. The suggested hybrid energy storage system (ESS) consists of electrochemical batteries and ultracapacitors (UCs). The regeneration of the AS energy improves fuel efficiency, according to the results of the simulations. To further enhance battery life and efficiency by adopting a hybrid energy storage system (ESS), load fluctuations from the batteries can be passed over to the UCs.

According to L. Wang, et. al, Optimal design and real-time control for electric vehicle energy management et. all.,[5] An active combination of an ultracapacitor (UC) and an energy-dense Li-ion battery has been proven to be a potential technique for electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs) to extend lithium-ion (Li-ion) battery cycle life (PHEVs). Using an optimization problem to reduce fuel usage, this article approaches the issue of battery and UC sizing, as well as the degree of hybridization between battery and UC power, from a fresh perspective. A unique energy management technique based on battery power reference generation, UC state-of-charge regulation, and forecast control based on driver orders is suggested to execute this optimum power sharing in real time. Finally, to validate that the suggested method reduces battery current stress and improves fuel economy, simulations and experiments using the flywheel + generator + controlled load is described.

Regenerative Braking Control for Light Electric Vehicles et. all.,[6] by Cheng-Hu Chen, Wen-Chun Chi, and Ming-Yang Cheng described a simple yet effective electric brake energy regeneration system for an electric vehicle's brushless DC motor (EV). To manage inverse torque during braking, a proposed solution merely alters inverter switching sequences. This means that the battery's braking energy is returned. By eliminating the need for a converter, ultracapacitor, or a complicated winding-changeover procedure, the proposed technology accomplishes both the electronic brake and energy regeneration aims simultaneously.

III.PROPOSED SYSTEM

Figure 1 depicts the regenerative braking system and its various components. An induction motor, three phase inverter, and a battery are all represented in the diagram below. For starters, the car travels down a straight road; if an impediment appears in the middle, the driver applies his brakes, and kinetic energy, in the form of electrolytic charge, is stored in the battery until it is full.

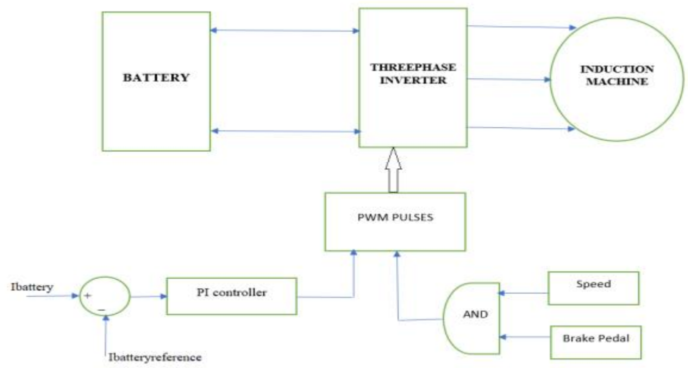

Fig 1. The Proposed system block diagram

A. Regenerative braking system

It is possible to use mechanical energy from the motor and transform it into electrical energy, which is then returned to the battery, in the form of regenerative braking. The motor slows the car downhill in the regenerative braking mode. Motor reverses direction and automobile slows down when the brake pedal is pressed. When the motor is going in the wrong direction, it serves as a generator, charging the battery. 3 This is depicted in the figure. 2 the typical operation of the car, where the motor gets energy from the battery and propels the vehicle ahead.

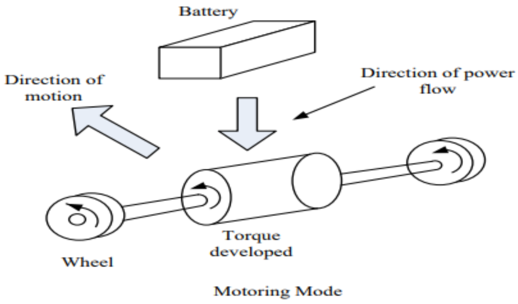

Fig 2: Normal driving condition

As a result of adopting regenerative braking, electric vehicles can save money on gas, while emissions are also reduced. When the speed of the vehicles is low, the electric vehicle's regenerative braking system supplies the braking force, which reduces the need for traffic stop and go and therefore deceleration.

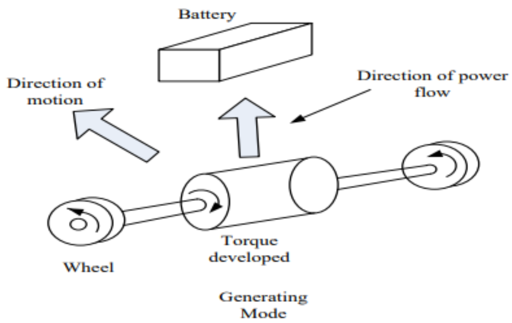

Fig 3 Regenerative action during braking.

When driving in such an environment, the brakes operate so well that you can stop in cities with ease. A vehicle's braking system and controller provides a sense of structure because it regulates the entire powertrain. There are two main roles of the brake controller: to monitor the wheel's speed, in order to compute the torque, the amount of electricity generated and the rotational force that will be fed into the battery. Controlling and directing electrical energy generated by a motor is done by a braking controller.

IV. CONTROL SYSTEM FOR EV

A. Normal mode

Figure 4 depicts how electric vehicles are operated. Positive to negative voltage flow through the armature current. Every MOSFET is connected to a diode in parallel. A freewheeling diode like this one can be used to switch devices using PWM, ensuring that the system's efficiency is at its highest level.

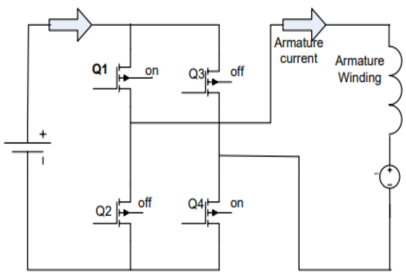

Fig-4: Driving mode

B. Regenerating mode

To change the direction of armature current, in first stage of initial braking mode the back-emf and the battery goes in the series connections shown in the battery and back-emf are connected in series during the first step of initial braking mode to change the direction of armature current Q2 and Q3 are activated while Q1 and Q4 are deactivated in this method of initial braking in order to allow the armature current to automatically change directions. To charge the battery again, the state of the MOSFETs returns to the position depicted in figure 5 when the armature current increases and changes direction on its own. Using this method, regenerative braking is made possible.

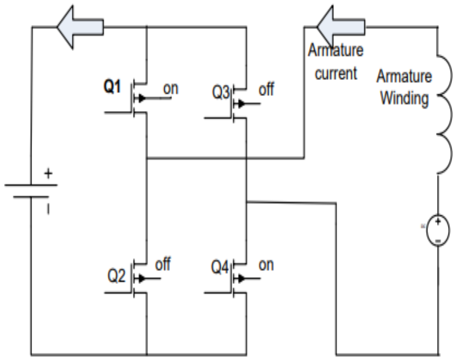

Fig-5: Regenerating mode

V. INDUCTION MOTOR

As a general rule, conversion of electrical power into mechanical power takes place in the rotating parts of an electrical motor. In dc motor, the power is conducted directly in armature the rotating part of the motor through brush and hence dc motor called as conduction motor but in case of induction motor the motor does not receive the electrical power by conduction but by induction in exactly same way as the secondary of a two-winding transformer receives its power from the primary. That is why such motor known as induction motor.

In fact, an induction motor can be treated as a rotating transformer i.e. one in which primary winding is stationary but the secondary is free to rotate. Of all the a.c. motors, the poly phase induction motor is the one which is extensively used for various kinds of industrial drives.

When a three-phase supply is connected to the stator windings, a rotating magnetic field is produced. As the magnetic flux cuts a bar on the rotor, an e.m.f. is induced in it and since it is joined, via the end conducting rings, to another bar one pole pitch away, current flows in the bars.

The magnetic field associated with this current flowing in the bars interacts with the rotating magnetic field and a force is produced, tending to turn the rotor in the same direction as the rotating magnetic field. Similar forces are applied to all the conductors on the rotor, so that a torque is produced causing the rotor to rotate.

The Speed of Induction Motor is changed from Both Stator and Rotor Side. The speed control of three phase induction motor from stator side are further classified as :

- V / f control or frequency control.
- Changing the number of stator poles.
- Controlling supply voltage.
- Adding rheostat in the stator circuit

The speed controls of three phase induction motor from rotor side are further classified as:

- Adding external resistance on rotor side.
- Cascade control method.
- Injecting slip frequency emf into rotor side.

Here V / f control or frequency control speed control method is used.

A. V / f control or frequency control method

Whenever three phase supply is given to three phase induction motor rotating magnetic field is produced which rotates at synchronous speed given by

$$N_s = \frac{120 * f}{P} \quad (1)$$

In three phase induction motor emf is induced by induction similar to that of transformer which is given by

$$E \text{ or } V=4.44 * K * f * T \text{ or } \emptyset = \frac{V}{4.44 * K * T * f} \quad (2)$$

Where, K is the winding constant, T is the number of turns per phase and f is frequency.

Now if we change frequency synchronous speed changes but with decrease in frequency flux will increase and this change in value of flux causes saturation of rotor and stator cores which will further cause increase in no load current of the motor . So, its important to maintain flux , φ constant and it is only possible if we change voltage. i.e if we decrease frequency flux increases but at the same time if we decrease voltage flux will also decease causing no change in flux and hence it remains constant.

So, here we are keeping the ratio of V/f as constant. Hence its name is V/ f method. For controlling the speed of three phase induction motor by V/f method we have to supply variable voltage and frequency which is easily obtained by using converter and inverter set.

VI. MATHEMETICAL MODELLING

A. Vehicle Modelling

The vehicle's resistance to movement is the traction motor's load. Figure 6 depicts the forces exerted on a vehicle as it travels down an incline. Vehicle lateral movement is affected by a variety of factors, including the following:

- Aerodynamic drag force
- Rolling resistance force
- Weight of the vehicle
- Longitudinal traction force

The algebraic difference between the traction force and the resistive force due to the vehicle load, determines the net force affecting the acceleration or the deceleration of the vehicle. This can be mathematically expressed as

$$F_{acclr} = F_x - F_{aero} - F_{roll} - F_{gravity} \quad (3)$$

The aerodynamic drag force acting upon the vehicle due to the speed of wind is calculated as

$$F_{aero} = \frac{\rho * C_d * A_f}{2} * (V_x + V_{wind})^2 \quad (4)$$

Part of the tyre is continuously depressed at the bottom as it rotates and then returns to its former shape when it exits the contact region. Due to damping effect, depression and release occur. Since the process uses energy, the rolling

resistance that slows the vehicle down is a result of this. Due to the vehicle's weight, the rolling resistance is normally proportional to the normal gravitational force.

$$F_{roll} = f_r * m_v * g * \cos(\alpha) \quad (5)$$

Thus, the difference between the vehicle's tractive force and the sum of the road loads (gravitational force, rolling resistance, and aerodynamic resistance) is utilised to accelerate the vehicle. ' The speed of a head wind is not taken into account because the vehicle is considered to be travelling on a horizontal road.

The torque at the motor shaft and the torque on the wheel axle can be related as

$$T_e * \eta_{dr} = \frac{T_w}{g_{dr}} \quad (6)$$

The vehicle traction power can be given as

$$P_x = T_e * \omega_r * \eta_{dr} * (1-s_x) \quad (7)$$

The motor shaft power is given as

$$P_e = T_e * \omega_r \quad (8)$$

The total efficiency between the motor shaft and the vehicle traction system is given as

$$\eta_f = \frac{P_x}{P_e} = \eta_{dr} * (1-s_x) \quad (9)$$

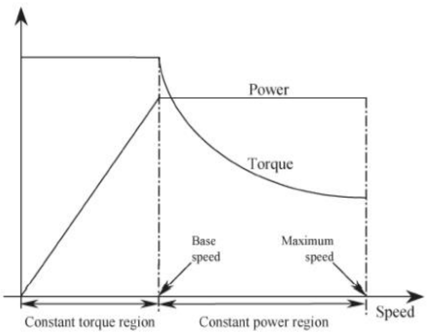

Fig.6. Characteristic of traction system

Figure 8 depicts the characteristic curve of a traction system, which is divided into two sections by the base speed:

1) Constant torque region, and

2) Constant power region.

The maximum tractive effort of EV is set to with the base speed as the pivot.

$$F_x=\left\{\frac{T_e * g_{dr} * \eta_{dr}}{r_w},\quad \omega_r \le \omega_b\right\}$$

$$F_x=\left\{\frac{P_e * \eta_f}{V_s},\quad \omega_r > \omega_b\right\} \tag{10}$$

where, Te is the electromagnetic torque developed by the motor shaft to drive the vehicle and Pe is the equivalent power developed at motor shaft. The load torque (TL) acting upon the machine is proportional to load force (FL) given by Eqn. 18. Thus, the load torque is proportional to the net resistive force due to aerodynamic drag and rolling resistance, when the vehicle is assumed to be moving on a flat surface.

Under this assumption, it can be concluded that the load acting upon the traction motor is proportional to the mass of the vehicle. Hence the vehicle load can be considered to be constant for simplification of analysis.

B. Modelling of Battery

The major means of storing energy for electric and hybrid vehicles is batteries. Electric vehicles (HEVs) employ rechargeable batteries to store and transmit energy to the machine system while travelling, while regenerative braking removes energy from the system (charging), and while the vehicle is not in use (storage).

Batteries used in automobiles need to have high specific power, high specific energy, high efficiency, safety, low cost, low maintenance, and environmental adaptability in order to be useful.

Circuit-oriented modelling and mathematical modelling are the two most used battery modelling approaches. Voltage and current sources, resistors, and capacitors are used to represent battery performance in a circuit-oriented battery model.

In addition to the Thevenin-based model, there are several more fundamental variants. Input/Output Impedance Relationship Third, a Runtime Model Models of this complexity, however, require two diodes that are in opposition to each other in order to establish the parameters of the battery and the state of charge of the battery. This complicates the system further.

Peukerts Model is used to model the Shepherd Equation. This is the most important sub model, which describes the change in terminal voltage as a function of current.

The Shepherd Equation is the starting point for this model, and it is then refined to better fit the charge and discharge curves. In this case, the most common lithium-ion battery for electric vehicles and hydrogen electric vehicles (HEVs) was employed as a mathematical model.

When it comes to describing battery performance during charging and discharging, state variables like voltage, current and state of charge (SOC) are used.

Battery electrochemical behaviour is described in Shepherd model terms of the battery terminal voltage, open-circuit current voltage, internal resistance and state of charge [17]. The charge and discharge properties of this device are well characterised.

The equivalent block diagram for the nonlinear Li-Ion battery model has been shown in figure 7

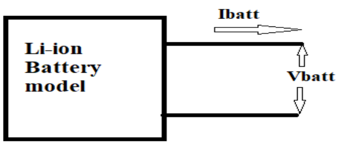

Fig.7 Equivalent block diagram for Li-ion battery

The battery modelling is predicated on the following premises:

- A constant internal resistance is maintained throughout both charging and draining regardless of the voltage. The parameters are taken from the discharge characteristics and assumed to remain constant when charging. Battery capacity is unaffected by the current's amplitude. This is not a Peukert Effect situation.
- Temperature has no effect on the model's behaviour.
- The battery's self-discharge is not taken into account. As far as we can tell, the model exhibits no memory effect. The battery model has the following constraints in design. The voltage of the no-load battery is 0 V at the lowest end, and 2EO V at the highest. There is a range of capacities for the battery, which can range from 0 to Q.

If the battery is overcharged, the SOC cannot be higher than 100%. Theoretically, the assumptions outlined above are correct, however in practise, the SOC limit varies from 20 to 40%. Lithium is one of the lightest metals, and it also has good electrical properties. This thesis was powered by a lithium-ion battery model because of its cited advantages.

VII. SIMULATION RESULTS

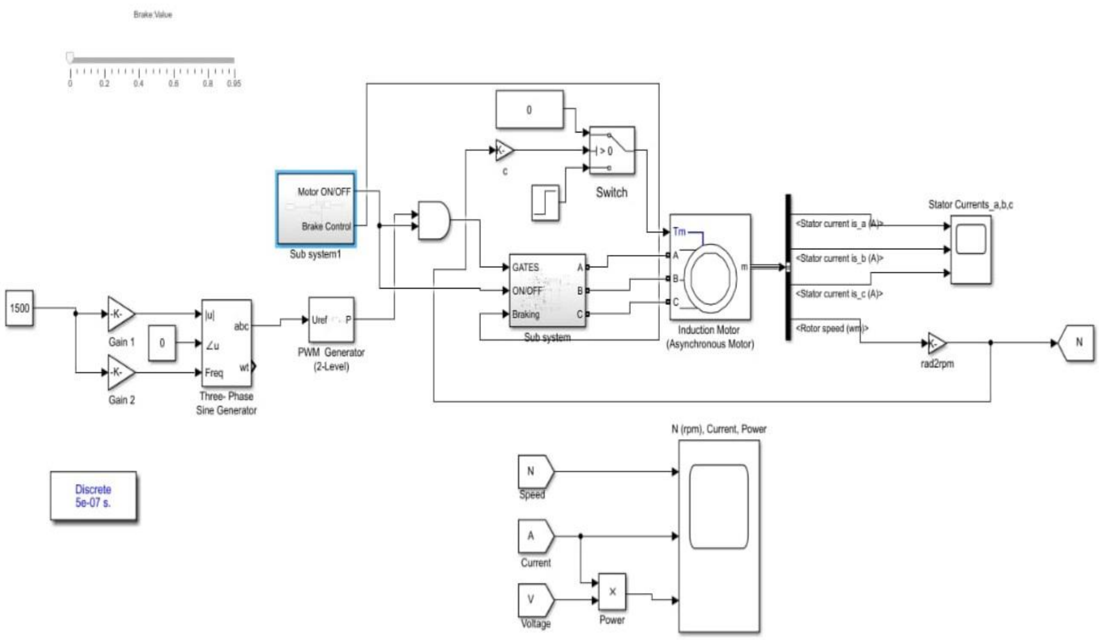

Fig.8. MATLAB/SIMULINK circuit diagram of the battery fed EV

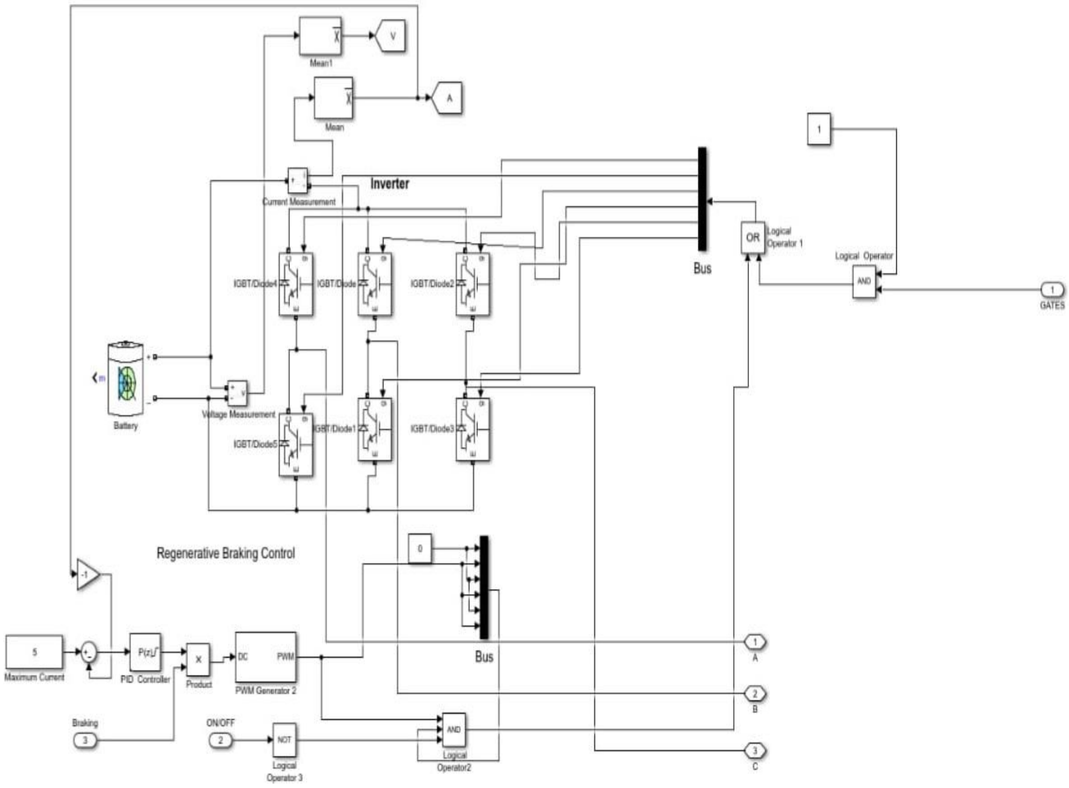

Fig.9 Subsystem of Battery with Inverter

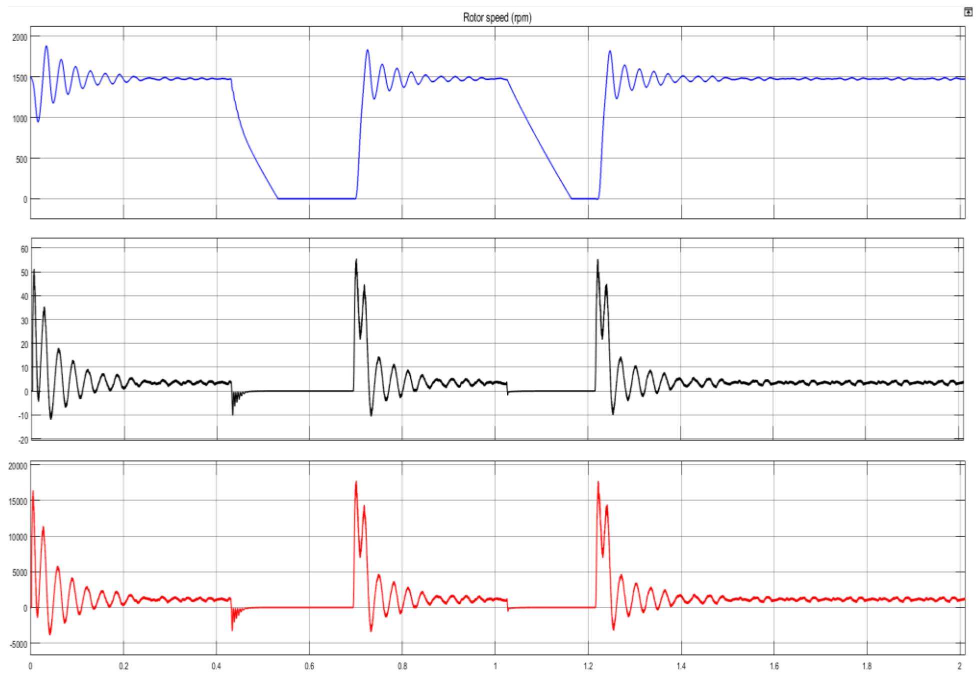

Fig.10 Rotor speed, Battery current and power

VIII. CONCLUSION

This study presents a novel RBS based on the utilisation of ESS for electric vehicles with induction motors. During regenerative braking and/or energy regeneration, the vehicle's kinetic energy is absorbed by energy storage. As a result, an interface for power electronics is no longer necessary. To maintain consistent torque braking, the duty cycle of the PWM is controlled by the PI controller in the PWM inverter.

.

REFERENCES

[1] Y. Kim, and N. Chang, ‘‘Design and management of energy-efficient hybrid electric energy storage systems,’’ springer, pp.19-25, 2014

[2] S. M. Lukic, J. Cao, R. C. Bansal, F. Rodriguez, and A. Emadi, “Energy storage systems for automotive applications,” IEEE Transactions on Industrial Electronics, vol. 55, no. 6, pp. 2258–2267, June 2008.

[3] S. G. Wirasingha, and A. Emadi, ‘‘Classification and review of control strategies for plug-in hybrid electric vehicles,’’ IEEE Trans. Veh. Technol., vol. 60, no. 1, pp. 111-122, Oct. 2010.

[4] M. Montazeri, and M. Soleymani, ‘‘Investigation of the energy regeneration of active suspension system in hybrid electric vehicles,’’ IEEE Trans. Ind. Electron., vol. 57, no. 3, pp. 918-925, Oct. 2009.

[5] L. Wang, E. G. Collins, and H. Li, ‘‘Optimal design and real-time control for energy management in electric vehicles,’’ IEEE Trans. Veh. Technol., vol. 60, no. 4, pp. 1419-1429, Mar. 2011.

[6] Cheng-Hu Chen, Wen-Chun Chi, Ming-Yang Cheng, “ Regenerative Braking Control for Light Electric Vehicles “ IEEE PEDS 2011, December 5-8, 2011.

[7] B. Enache et al., “Comparative study for generic battery models used for electric vehicles,” 8th International Symposium on Advanced Topics in Electrical Engineering (ATEE), pp. 1-6, 23-25 May 2013.

[8] H. L. Chan, “A new battery model for use with battery energy storage systems and electric vehicles power systems,” in Proc. 2000 IEEE Power Engineering Society Winter Meeting, vol. 1, pp. 470-475, 2000.

[9] H. L. Chan, “A new battery model for use with battery energy storage systems and electric vehicles power systems,” in Proc. 2000 IEEE Power Engineering Society Winter Meeting, vol. 1, pp. 470-475, 2000.

[10] Lijun Gao et al., “Dynamic lithium-ion battery model for system simulation,” IEEE Trans. Compon. Packag. Technol., vol. 25, no. 3, pp. 495-505, Sep 2002.

[11] H. A. Hairik et al., “Proposed scheme for plugging three-phase induction motor,” 15th IEEE Mediterranean Electro technical Conf., MELECON, pp. 1-5, 26-28 April 2010.

[12] H. A. Hairik et al., “Proposed scheme for plugging three-phase induction motor,” 15th IEEE Mediterranean Electro technical Conf., MELECON, pp. 1-5, 26-28 April 2010.

[13]Okan TUR,Ozgur USTUN, Member IEEE, and R.Nejat TUNCAY, “An Introduction to Regenerative Braking of Electric Vehicles as Anti- Lock Braking System”,IEEE june 13-15 2007.

[14] Beck et al., “Plugging an Induction Motor,” IEEE Trans. Industry and General Applications, vol. IGA-6, no. 1, pp. 10-18, Jan. 1970

[15] A. Fazeli, M. Zeinali, and A. Khajepour, ‘‘Application of adaptive sliding mode control for regenerative braking torque control,’’ IEEE/ASME Trans. Mechatronics, vol. 17, no. 4, pp. 745-755, April 2011.

[16] S. de la Torre, A. J. Sánchez-Racero, J. A. Aguado, M. Reyes, and O. Martianez, ‘‘Optimal Sizing of Energy Storage for Regenerative Braking in Electric Railway Systems,’’ IEEE Trans. Power Syst., vol. 30, no. 3, pp. 1492-1500, Aug. 2014.

[17] M. Mortazavi, M. Mastali, and A. A. Safavi, ‘‘Enhanced Neural Network Based Fault Detection of a VVER Nuclear Power Plant With the Aid of Principal Component Analysis,’’ IEEE Trans. Nucl. Sci., vol. 55, no. 6, pp. 3611-3619, Dec. 2008.

[18] K. Inoue et al., “A Study on an Optimal Torque for Power Regeneration of an Induction Motor,” Conf. IEEE Power Electronics Specialists, pp. 2108-2112, 17-21 June 2007.

[19] S. D. Sudhoff et al., “An induction machine model for predicting inverter-machine interaction,” IEEE Trans. Energy Convers. , vol. 17, no. 2, pp. 203-210, Jun 2002.

[20] O. Wasynczuk et al., “A voltage control strategy for current-regulated PWM inverters,” IEEE Trans. Power Electron., vol. 11, no. 1, pp. 7-15, Jan. 1996.

[21] M. Ehsani et al., “Propulsion system design of electric and hybrid vehicles,” IEEE Trans. Ind. Electron., vol. 44, no. 1, pp. 19-27, Feb. 1997. [39] N. Mutoh et al., “A torque controller suitable for electric vehicles,” IEEE Trans. Ind. Electron., vol. 44, no. 1, pp. 54-63, Feb. 1997

[22] G. Hongwei, G. Yimin, and M. Ehsani, ‘‘A neural network based SRM drive control strategy for regenerative braking in EV and HEV,’’ Electric Machines and Drives Conference, pp. 571-575, June 2001

[23] Yang, M.-J.; Jhou, H.-L.; Ma, B.-Y.; Shyu, K.-K. A cost-effective method of electric brake with energy regeneration for electric vehicles. IEEE Trans. Ind. Electron. 2009, 56, 2203–2212.

[24] M. K. Yoong et al., “Studies of regenerative braking in electric vehicle,” Conf. IEEE Sustainable Utilization and Development in Engineering and Technology (STUDENT), pp. 40-45, 20-21 Nov. 2010

[25] M. Collie, Electric and Hybrid Vehicles. Energy Technology Review No. 44, New Jersey, USA, Noyes Data Corporation, 1979