Experimental Verification of a Regenerative Braking System with an SOC Based Energy Management System for an E-Rickshaw Motor

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Abstract. *E-rickshaws are relatively new additions to India's public road transportation system, gaining popularity as a convenient and cost-effective means of commuting for fellow travelers. However, they do not come equipped with a regenerative braking system. This paper proposes a simple and cost-effective regenerative braking system for e-rickshaw motors, incorporating an energy management system based on the state of charge of the battery. The proposed system can function effectively even when the battery is fully or nearly fully charged. Additionally, it eliminates the need for any supplementary current or voltage sensors, significantly reducing the circuit's complexity and cost. To evaluate the system's performance under various traction conditions, simulations, and tests are conducted using the MATLAB/Simulink model. The results confirm the high capabilities of the proposed system. The functionality and effectiveness of the proposed regenerative braking system are validated through laboratory experiments conducted under various conditions, including different speeds and levels of braking force, on a prototype equipped with an e-rickshaw motor. The results of the experiments demonstrate that the proposed regenerative braking system is successful in achieving its intended purpose, even with the fully charged battery, and without the need for any additional current sensors or voltage sensors. The proposed regenerative braking system not only enhances the efficiency and sustainability of e-rickshaws but also contributes to reducing overall energy consumption and environmental impact. As a result, this innovative solution holds great potential for widespread adoption in India's growing e-rickshaw industry.*

Keywords

Regenerative braking system, Energy management system, Boost converter, BLDC Motor.

1. Introduction

E-rickshaws are three-wheeled vehicles with five seats that are widely utilized as the primary means of public transit in Indian cities, primarily for short-distance transportation and last-mile connections. Their maximum speed is limited to 25 km/h, and their motor capacity is up to 2 kW. In India, e-rickshaws have an average range of 80 kilometers. There are 1.5 million battery-powered e-rickshaws, and eleven thousand new e-rickshaws are hitting the road every month, serving over 60 million people every day who require economic mobility [1].

1.1. Literature Review

The traditional e-rickshaws are very well suited to Indian traffic conditions. Their small size facilitates their manoeuvrability on congested roads. Table 1 gives the specifications of a popular e-rickshaw available in Indian market.

Tab. 1: E-rickshaw Specifications

Particulars	Specifications
Seating Capacity	4P+D
Diamensions(LBH)	2758*998*1770mm
Vehicle kerb weight	282kg
Vehicle Loading capacity	682kg
Top speed	25km/h
Motor Power	1000W
Motor Type	BLDC Motor
Transmission Type	Direct Drive
Roof Type	Hard top
Brakes Mechanical	Drum brake
Battery	Li-Ion, 100Ah, 48V

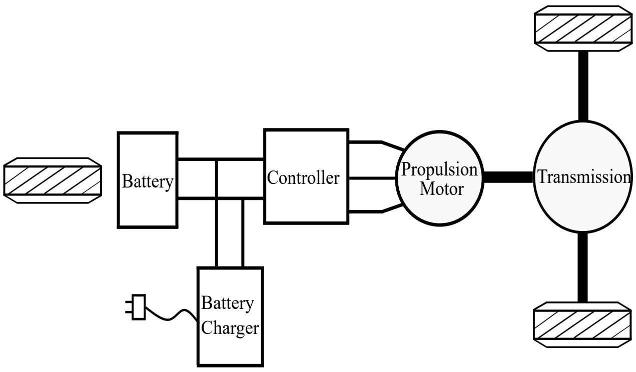


Fig. 1: Drive train configuration of e-rickshaw

The drive train configuration of an e-rickshaw shown in Fig. 1, consists of battery, controller, drive motor, and transmission. BLDC motors are commonly used in e-rickshaws and powered by lead-acid or Li-Ion batteries. E-rickshaws are currently not equipped with RBS due to an exemption granted to them by the Ministry of Heavy Industry and Public Enterprises through the FAME 2 guidelines and notifications.

There have been numerous studies conducted in the past and present to increase EV's range. Diverse techniques for boosting an EV's range and fuel efficiency have been described in the literature. All the various components of the EV drive line are now making contributions to the effort to solve the range extension challenge. [2] and [3] presents a topological analysis of the power trains for EVs with range extenders and [4] discusses few key EV technologies. Since battery serves as the primary energy source in EVs, great consideration has been given to battery technology to make it reliable and long-lasting. Li-Ion batteries when compared to their other equivalents, have a higher energy density and a longer lifespan [5, 6].EV range extension is also made possible by system-level modeling of a battery pack's effective cell balancing circuit [7]. By maintaining an ideal temperature, the battery's lifespan and EV range have both been increased [8]. Literature [9] presents an energy-optimal control method for improving the motor drive system's efficiency and extending the driving range of EVs.

The above strategies for extending range includes lowering and optimizing power consumption or boosting the battery capacity. Incorporating a RBS to recover energy lost during mechanical braking is another way to increase the range. The friction between the wheels and the brake pads dissipates the vehicle's stored energy as heat when it applies its brakes. This heat will be carried away by the air stream. Vehicle kinetic energy is stored in short-term storage devices during regenerative braking. Studies [10] reveal that an effective RBS design can extend the driving range by 16%.

E-rickshaws commonly employ BLDC motors due to their favorable torque-speed characteristics, efficiency, longevity, wide operating range, and low maintenance requirements [11]. Regenerative braking can be implemented effectively in BLDC motors, requiring the back EMF to exceed the battery voltage for recharging [12]. A modular RBS for electric scooters is proposed in [13] at low speeds. The suggested arrangement additionally proposes swift transitions between the motoring and regenerative modes through the activation or deactivation of gate pulses to the inverter or DC/DC boost converter. Another study [14] introduces a novel regenerative braking control strategy incorporating braking intensity definition, dynamic distribution for front and rear axles based on slope information, and a logic threshold control algorithm. A Fuzzy adaptive control algorithm proposes in [15], enhance energy recovery during regenerative braking and decrease vehicle weight. Exploring the impact of regenerative braking on Li-Ion battery life, [16] suggests protective measures against excessive charging, highlighting the importance of managing charging current for long-term battery health. A comprehensive literature review on the current and previous state of regenerative braking circuit topologies is presented in Table 2, and its simplified block diagrams are shown in Fig. 2. However, [17]-[27] do not provide any method to regulate the battery charging current during regenerative braking, especially when the battery is fully charged or close to being fully charged.

This paper addresses the practical implementation of a RBS in an e-rickshaw that is both simple and effective, with the goal of extending the driving range without causing damage to the battery. In this work, a simple regenerative braking technique for e-rickshaws is presented, which can be applied effectively even when the battery is fully or almost fully charged. To control the battery charging current, an EMS based on SOC is

Tab. 2: Regenerative braking circuit topologies

Reference	Topologies	Remarks
Bharmi et.al [17], Yang et.al [18], Deepa et.al [19], Soylu et.al [20], Heydari et.al [21], Godfrey et.al [22], Nian et.al [23], Zang et.al [24], Xu et.al [25]	Fig. 2-a	Regenerative braking energy is transferring directly to battery.
Ortuzar et.al [26]	Fig. 2-b	Regenerative braking energy is transferring to Ultracapacitor. Since Ultracapacitor is very costlier its implementation is not economical in e-rickshaws.
Lee et.al [27]	Fig. 2-c	Regenerative braking energy is transferring directly to battery.

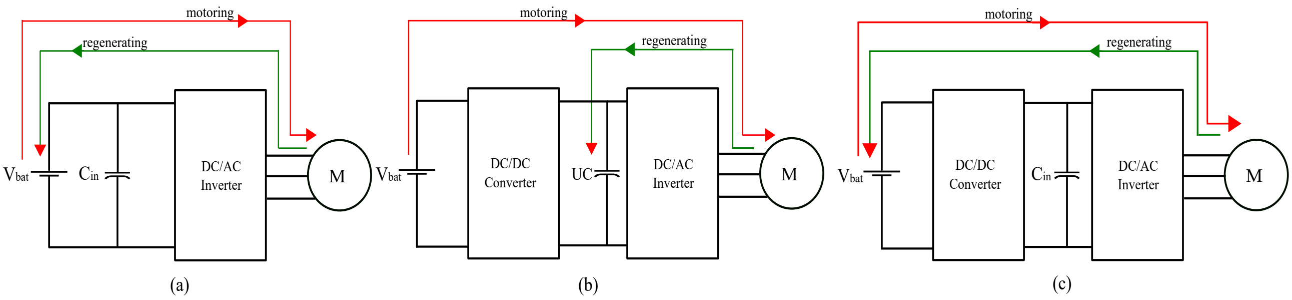


Fig. 2: Regenerative braking circuit topologies

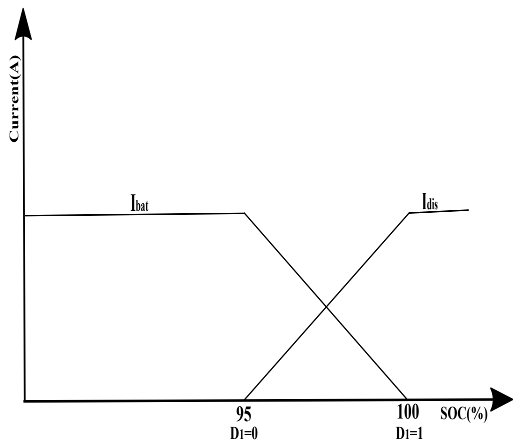


Fig. 3: Regeneration current profile

battery charging current, an EMS based on SOC is integrated and analyzed through experiments to ensure its feasibility

The Li-Ion batteries typically undergo charging in CC-CV mode. In fast charging the operation switches from CC mode to CV mode once the SOC reaches 95% to prevent thermal runaway [28, 29]. The proposed technique involves feeding back only a portion of the regenerative power to the battery and dissipating the remaining portion in a resistor, if the battery SOC is above 95%. The current profiles of the battery and resistor during regenerative braking wrt. SOC is depicted in Fig. 3. When the battery SOC is above 95%, the battery charging current during regeneration reduces while the dissipating resistor current increases.

integrated and analyzed through experiments to ensure its feasibility

1.2. Novel contributions

This paper addresses the practical implementation of a RBS in an e-rickshaw that is both simple and effective, with the goal of extending the driving range without causing damage to the battery. In this work, a simple regenerative braking technique for e-rickshaws is presented, which can be applied effectively even when the battery is fully or almost fully charged. To control the

1.3. Paper organization

The rest of this paper is organized as follows. Section 2. presents the basics of BLDC motor along with motoring operation and regenerating braking operation. Section 3. describes the operation of the proposed RBS. Section 4. is dedicated for the modeling and analysis of the proposed regenerative braking system. The simulation study is discussed in section 5. and experimental results included in section 6. . Section 7. deals with the conclusion of the proposed regenerative braking system.

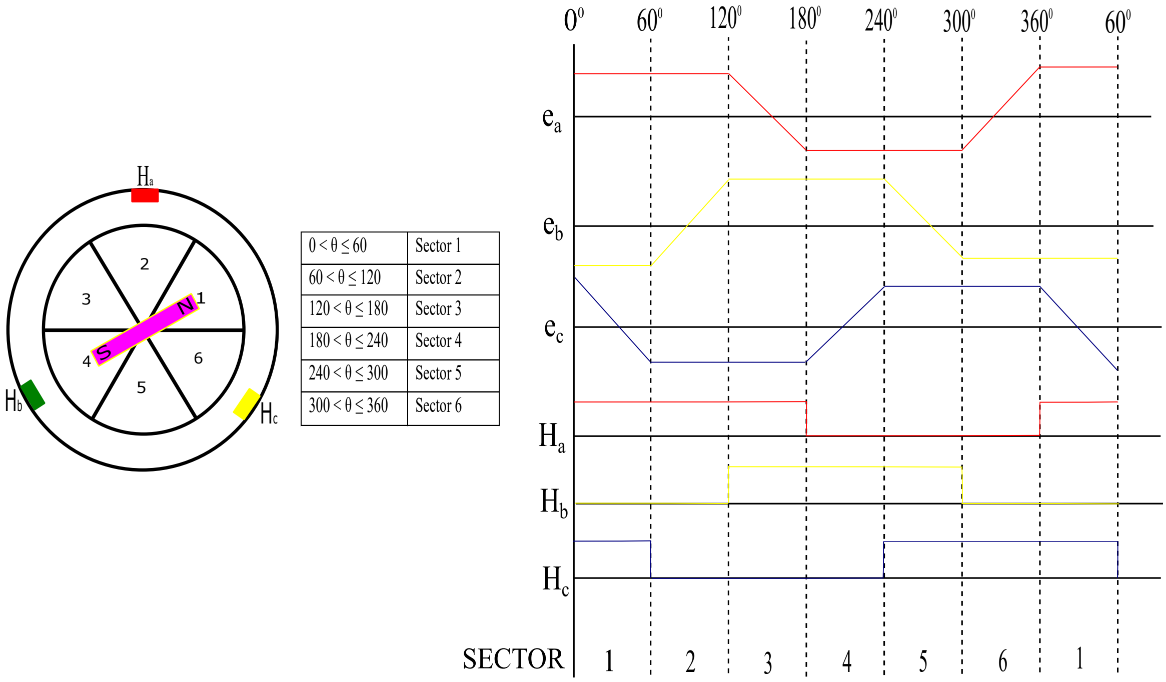


Fig. 4: Sectors and back emf waveforms in BLDC motor

2. BLDC motor and control

2.1. Basics of BLDC motor

The primary application for BLDC motors, which resemble synchronous motors, is in the automotive industry. The stator magnetic field and the rotor magnetic field rotate at the same speed. The permanent magnets are placed on the rotor and the armature windings are arranged in the stator. The interior space of the BLDC motor is divided into six sectors. Fig. 4 shows the sectors and corresponding back emf wave forms. The commutation logic is developed based on the position of the rotor wrt. this sectors.

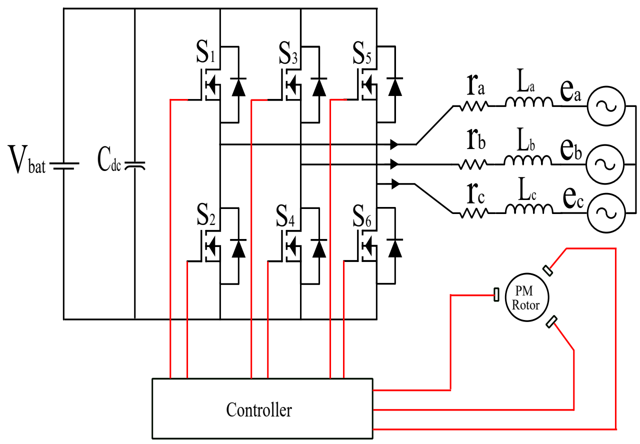


Fig. 5: The basic drive circuit of a BLDC motor

2.2. Motoring Operation

The BLDC motor drive circuit is illustrated in Fig. 5. It operates by energizing one pair of stator windings successively, depending on the rotor's position. Therefore, the position of the rotor is critical for the continuous rotation of the motor. The lower side and upper side driver switches on each motor lead are used to commutate the motor. To determine the location of the rotor, hall effect sensors are typically used. Based on hall sensor signals, the controller generates necessary PWM signals for the inverter.

2.3. Regenerative Braking Operation

In a BLDC motor, regenerative braking is achieved by reversing the direction of the electrical current flowing through the motor. Instead of supplying electrical power to the motor to make it turn, the motor generates electrical power as it slows down, which is then fed back into the battery or other electrical system. But even at full throttle, the motor's maximum back emf is less than the battery voltage. Therefore, the back EMF must be boosted above the battery voltage. The winding inductances of the motor can be used to boost the back EMF. There are different regenerative braking topologies in BLDC motors which includes single switch, two-switch and three switch methods.

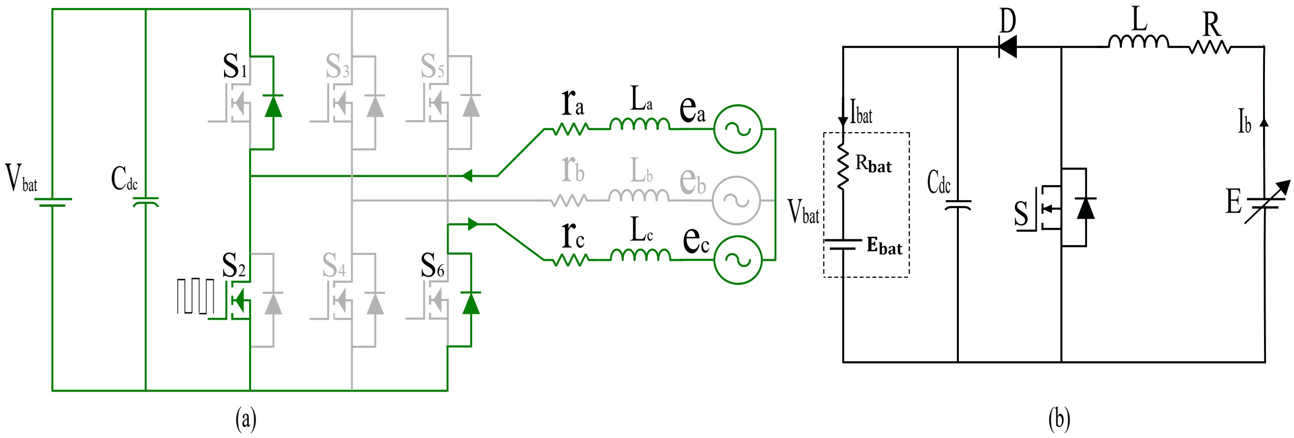


Fig. 6: Regenerative braking operations in Sector 2. and its equivalent circuit

In single switch strategy, there is only one power switch operated within each commutation state. During regenerative braking, the switches on the upper arms of the inverter are turned off and the lower arms of the inverter are controlled with PWM signals in each commutation state. Fig. 6(a) shows the current flow in sector 2. Phase a is positive and c is negative. PWM signal are applied to the switch S_2. When the switch S_2 is on, energy is stored in the winding inductance. When the switch is off this stored energy will flow to the battery through the antiparallel diode connected across S_1 and S_6. The same strategy is implemented for other sectors also to get the continuous current flow at the time of braking. Thus the equivalent circuit of the regenerative braking constitutes a boost circuit as shown in Fig. 6(b). The rate at which the vehicle's stored energy is transferred to the battery determines the motor's deceleration. Therefore, the deceleration of the motor at the time of regenerative braking can be controlled by the duty ratio of the boost converter or in other words, by varying the duty ratio of the PWM signal to the power switch undergoing commutation.

3. Proposed RBS

3.1. Structure and Working

The circuit diagram of the proposed RBS is shown in Fig. 7(a) and its equivalent circuit is shown in Fig. 7(b).In the proposed circuit, if the battery SOC $\leqslant$ 95% the relay contact R_1 is closed and regenerative braking takes place in single switch strategy. The simplified equivalent circuit for this case is shown in Fig. 7(c). If SOC is above 95%, the relay contact R_1 open and only a portion of the regenerative braking power is fedback to the battery. Remaining portion of the regenerative braking power is dissipated in the resistor R_D connected across the dc bus. In this mode, the switches Sa and Sb are operated in such a manner that only safe power flows to the battery depends upon the SOC. The simplified equivalent circuit is shown in Fig. 7(d).

3.2. Control Strategy

To ensure efficient operation, two distinct control strategies have been developed. The first pertains to the single-switch regenerative braking system, while the second relates to the current dissipation circuit that operates when the battery SOC exceeds 95%. These control strategies are depicted in Fig. 7(e) and Fig. 7(f), respectively, and is discussed in detail below.

1) Control Scheme-RBS

The control scheme in single switch regenerative braking strategy is depicted in Fig. 7(e). This system incorporates a potentiometer which is located in the brake pedal and produces a voltage that is proportional to the degree of depression of the pedal within a range of 0 to 5 volts. During regenerative braking, the upper side switches are disabled, while the lower side switches of the inverter are provided with pulse width modulation signals based on the rotor position. The duty cycle of these PWM signals is proportional to the displacement angle of the brake pedal, as measured by the potentiometer voltage. However, the maximum duty cycle for regenerative braking is limited to 95%.

2) Control Scheme - EMS

In an e-rickshaw, when integrating the regenerative braking system with the battery to extend the driving range, an EMS is essential to prevent the false charging of the battery when battery is fully or nearly fully charged state. The proposed EMS receives brake status and battery SOC as inputs. Based on the control algorithm, the proposed EMS determines the operation

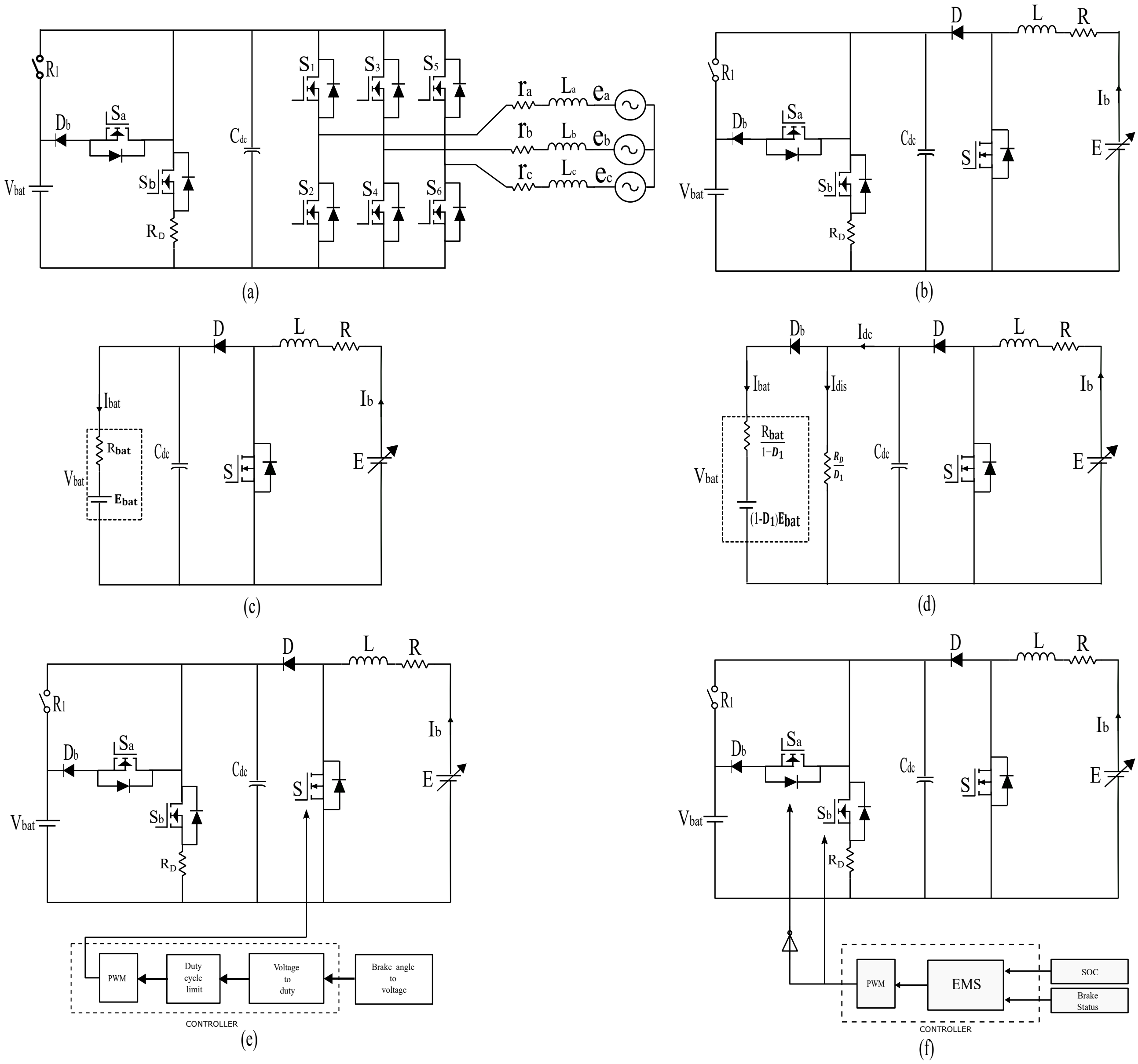
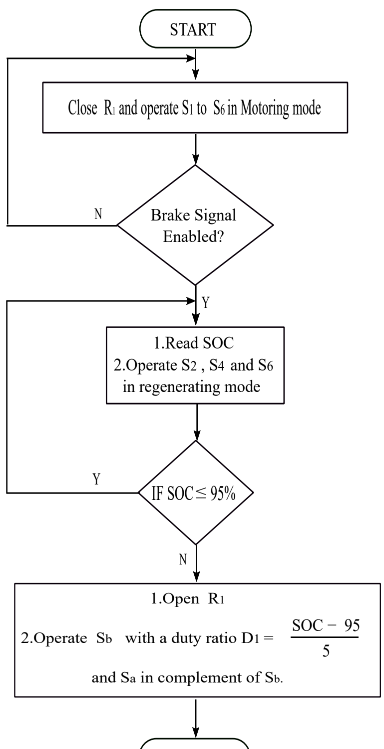


Fig. 7: Proposed RBS with equivalent circuits and control schemes

of the relay contact and duty ratio of the switches S_a and S_b. If battery SOC is $> 95\%$, to limit the battery charging current, the dissipating resistor R_D has to operate. The duty ratio of the S_b is given by

$$D_1 = \frac{SOC - 95}{5}. \quad (1)$$

The complement of S_b is given to S_a. As a result, only safe power is transferred to the battery, generating the same deceleration at the time of regenerative brakings, irrespective of the SOC of the battery. The control scheme of the EMS is shown in Fig. 7(f). The functions of the proposed EMS are described in Table 3. The control algorithm of the proposed SOC based EMS for RBS is explained with the flow chart shown in Fig. 8.



Tab. 3: Functions of Energy Management System

Operating mode	Cases	Functions of EMS
Motoring		Close R_1
Regenerating	SOC $> 95\%$	1. Open R_1 and operate S_2, S_4 and S_6 in regenerating mode. 2. Operate S_b with a duty ratio $D_1 = \frac{SOC-95}{5}$ and S_a in compliment of S_b.
	SOC$\leq 95\%$	Close R_1 and operate S_2, S_4 and S_6 in regenerating mode.

4. Modeling and Analysis of the Proposed RBS

The modeling of the RBS is done by considering the line back EMF, E as the input voltage during regeneration. In the first case ie. when SOC $\leqslant 95\%$, battery is the only load. In this paper, the battery is modeled by its simple equivalent circuit which consists of Ebat in series with Rbat. When SOC is above 95%, the effect of the dissipating resistor is considered. The energy transferred to the battery can be expressed as

$$W_{bat} = \int_{t_1}^{t_2} (V_{bat} I_{bat}) dt. \tag{2}$$

4.1. Case-1: SOC $\leqslant 95\%$

If battery SOC $\leqslant 95\%$ the entire regenerating power can fedback to the battery. The equivalent circuit is as shown in Fig. 7(c). From the principle of the volt-second balance, the net change in the equivalent inductor voltage is zero over one electric cycle. Therefore,

$$\int^{T} V_L dt = DT[E - I_b R] + (1 - D)T[E - I_b R - V_{bat}] = 0. \tag{3}$$

From (3) The braking current at the time of regeneration

$$I_b = \frac{E - V_{bat}(1 - D)}{R}. \tag{4}$$

$$Braking\ torque, T_b = K_t * I_b. \tag{5}$$

Neglecting the losses, the power balance equation at any time of regenerative braking, can be written as

$$\frac{d}{dt}\frac{1}{2}(J\omega^2) = V_{bat} I_{bat}. \tag{6}$$

$$J\omega\alpha = V_{bat} I_{bat}. \tag{7}$$

$$Motor\ deceleration, \alpha = \frac{V_{bat} I_{bat}}{J\omega}. \tag{8}$$

The Battery charging current can be expressed as

$$I_{bat} = I_b(1 - D). \tag{9}$$

$$I_{bat} = \frac{[E - V_{bat}(1 - D)](1 - D)}{R}. \tag{10}$$

4.2. Case-2: SOC $> 95\%$

If battery SOC $> 95\%$ the entire regenerating power cannot be fed back to the battery. The equivalent circuit is shown in Fig. 7(d). A part of the regenerative braking power proportional to the SOC above 95% is dissipated in R_d.

The braking current at the time of regeneration

$$I_b = \frac{E - V_{bat}(1 - D)}{R}. \tag{11}$$

$$Braking\ torque, T_b = K_t * I_b. \tag{12}$$

The dc bus current,

$$I_{dc} = \frac{[E - V_{bat}(1 - D)](1 - D)}{R}. \tag{13}$$

The dissipating resistance current,

$$I_{dis} = \frac{V_{bat} D_1}{R_D}. \tag{14}$$

The Battery charging current is the difference of dc bus current and dissipating resistance current

$$I_{bat} = I_{dc} - I_{dis}. \tag{15}$$

Neglecting the losses, the power balance equation at any time of regenerative braking can be written as

$$\frac{d}{dt}\frac{1}{2}(J\omega^2) = V_{bat}^2 \frac{D_1}{R_D} + V_{bat} I_{bat1}. \tag{16}$$

$$J\omega\alpha = V_{bat}^2 \frac{D_1}{R_D} + V_{bat} I_{bat1}. \tag{17}$$

$$Motor\ deceleration, \alpha = \frac{V_{bat}^2 \frac{D_1}{R_D} + V_{bat} I_{bat1}}{J\omega}. \tag{18}$$

Tab. 4: Simulation Parameters

Parameters	Values
Stator resistance/phase	0.325Ω
Stator inductance/phase	0.4mH
Flux linkage	0.05Wb
Inertia	0.02kg-m^2
Pole pair	2
Switching frequency	10kHz

4.3. Design of Dissipating Resistor

The design criteria for dissipating resistor is that in both the cases, for the same brake potentiometer voltage the deceleration should be same.Therefore for same deceleration from (8) and (18)

$$V_{bat}I_{bat} = V_{bat}^2\frac{D_1}{R_D} + V_{bat}I_{bat1}. \tag{19}$$

$$R_D = \frac{V_{bat}D_1}{I_{bat} - I_{bat1}} \tag{20}$$

If $D_1 = 1$, $I_{bat1} = 0$. Therefore the dissipating resistance,

$$R_D = \frac{V_{bat}}{I_{bat}} = Equi.\ resistance\ of\ the\ battery \tag{21}$$

5. Simulation Study

The primary goal of the simulation study is to analyze the dynamic response of the proposed RBS. The various parameters used for the simulation are given in Table 4. The simulation study utilized the parameters of the motor in Table 1. Simulating the entire vehicle falls beyond the scope of this paper. Hence, making the following assumptions for the simulation study.

- Depending on the brake force given by the rider, speed is slowed down.
- The braking force is represented by 0-5V. The duty of the boost converter is proportional to this applied potentiometer voltage and the maximum duty is limited at 95%
- The simulation is carried out for 5s and regenerative braking is applied at 4s, for a duration of 1s.
- The regenerative braking is applied for a duty ratio of 80% at 3500RPM
- The regenerative braking is applied for SOC=90%, 96% and 99%.

The suggested system with specifications listed in Table 4 is modeled and tested using Simulink to evaluate performance at different SOCs. The results are shown in Fig. 9 to 11. In Fig.9, at 4s regenerative braking commences with a duty ratio of 80%, since SOC is below 95%, the entire regenerative braking energy is fedback to the battery. In Fig. 10, since SOC is 96%, a portion of regenerative braking power is wasted in the dissipating resistor. The dissipating resistor consumes nearly 5A while the battery is charged initially with 15A, which can be validated using the equation 14. In Fig. 11, SOC is 99%, dissipating resistor consumes 18A initially but battery current is near 2A. In all cases, the speed drops from 3500 rpm to 2000 rpm during the regenerative braking period. The negative battery current demonstrates regenerative braking, confirmed by the battery SOC profile. SOC decreases during driving and increases during regenerative braking.

The suggested RBS is proficient in generating the necessary braking torque to decrease the speed of the motor and simultaneously charge the battery, while also ensuring the battery safety.

6. Experimental Results

The experimental setup, shown in Fig. 12 consists of a BLDC motor attached with a flywheel and the specifications are listed in Table 5. The experiment is successfully conducted in the FPGA (WAVECT) environment, exploring various speeds, braking forces, and SOC levels. The FPGA controller generates PWM signals for the inverter, dissipating resistor switches, and manages relay contact based on SOC levels.

Fig. 13 illustrates the current, voltage, and speed waveforms recorded at 3100 rpm and 70% SOC. The motor starts at 10s, and regenerative braking is applied at 30s for all cases. At 10s, there is a dip in the DC bus voltage due to the high starting current of the BLDC motor.

In Fig. 13(a), regenerative braking with a duty ratio of 90% is applied at 30s. The motor comes to a stop in three seconds. Effective regenerative braking is evident from the negative DC bus current. The rise in DC bus voltage during regenerative braking is a result of the boost action of the circuit.

In Fig. 13(b), regenerative braking with a duty ratio of 60% is applied. Consequently, the rise in battery current and DC bus voltage magnitude decreases during regenerative braking, and the speed reduces to zero rpm in six seconds.

Fig. 13(c) shows regenerative braking with a duty ratio of 30%, resulting in the speed reducing to zero in nine seconds. In Fig. 13(d) the motor stops without regenerative braking, taking ten seconds to halt.The experimental results for Case 1 (SOC $\leqslant$ 95%) are tabulated in Table 6.

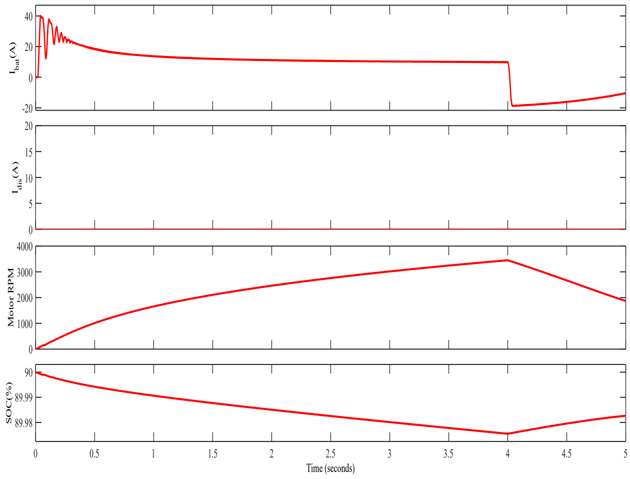


Fig. 9: Regeneration waveforms at 90% of SOC

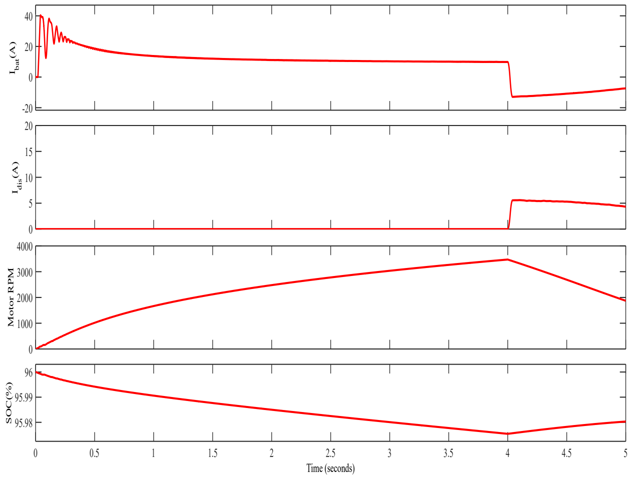


Fig. 10: Regeneration waveforms at 96% of SOC

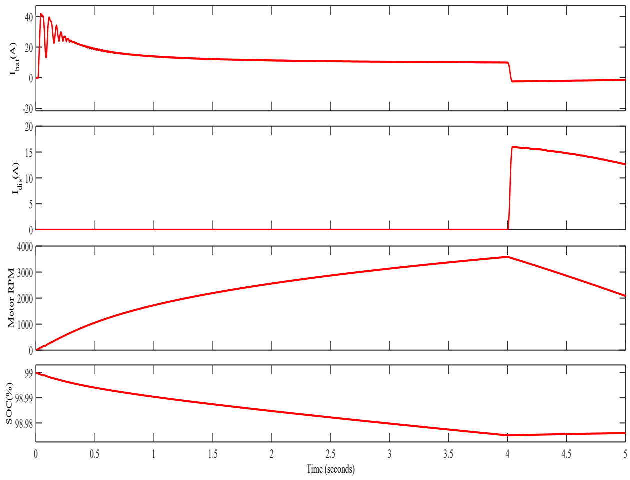


Fig. 11: Regeneration waveforms at 99% of SOC

Tab. 5: Specifications-Experimental Setup

Particulars	Specifications
BLDC Motor	48V , 900W, 3500rpm
Battery pack	Li-Ion, 48V, 36Ah
Inverter	5kW IGBT Stack
Controller	WAVECT WCU300
Flywheel inertia	0.01kg-m^2

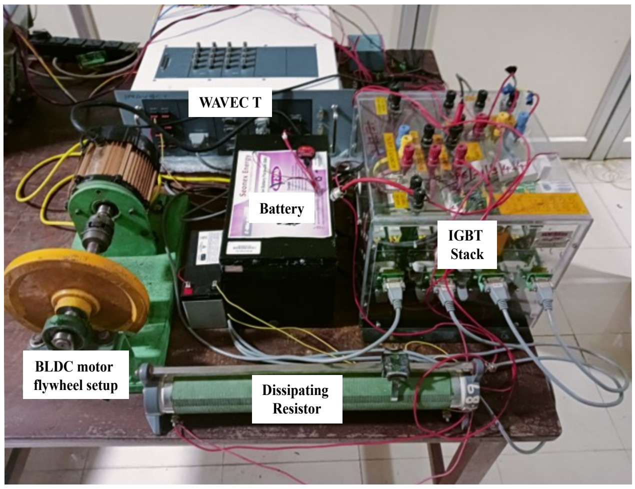


Fig. 12: Experimental Setup

Fig. 14 illustrates the relationship between the percentage of energy recaptured during regenerative braking and the speed of the vehicle. It is evident that the energy recovery rate rises as the speed increases. On the other hand, Fig. 15 provides a visual representation of the stop times corresponding to different brake duty ratios. This effectively showcases how altering these duty ratios affects the deceleration characteristics of the motor.

Fig. 16 shows the current, voltage, and speed waveforms recorded at 3200 rpm and brake duty ratio 90%. In Fig. 16(a), with a SOC of 96%, a portion of the braking power is dissipated in the dissipating resistor, and 50J of power is fed back to the battery, demonstrating effective energy recovery. In Fig. 16(b), with a SOC of 99%, the system prioritizes battery safety by dissipating a significant amount of braking power in the resistor, resulting in only 10J of power being fed back to the battery. Despite these variations, both cases achieve the desired motor stop within three seconds during the braking process, demonstrate the system's adaptability and reliability. The experimental results for Case 2 (SOC > 95%) are tabulated in Table 7.

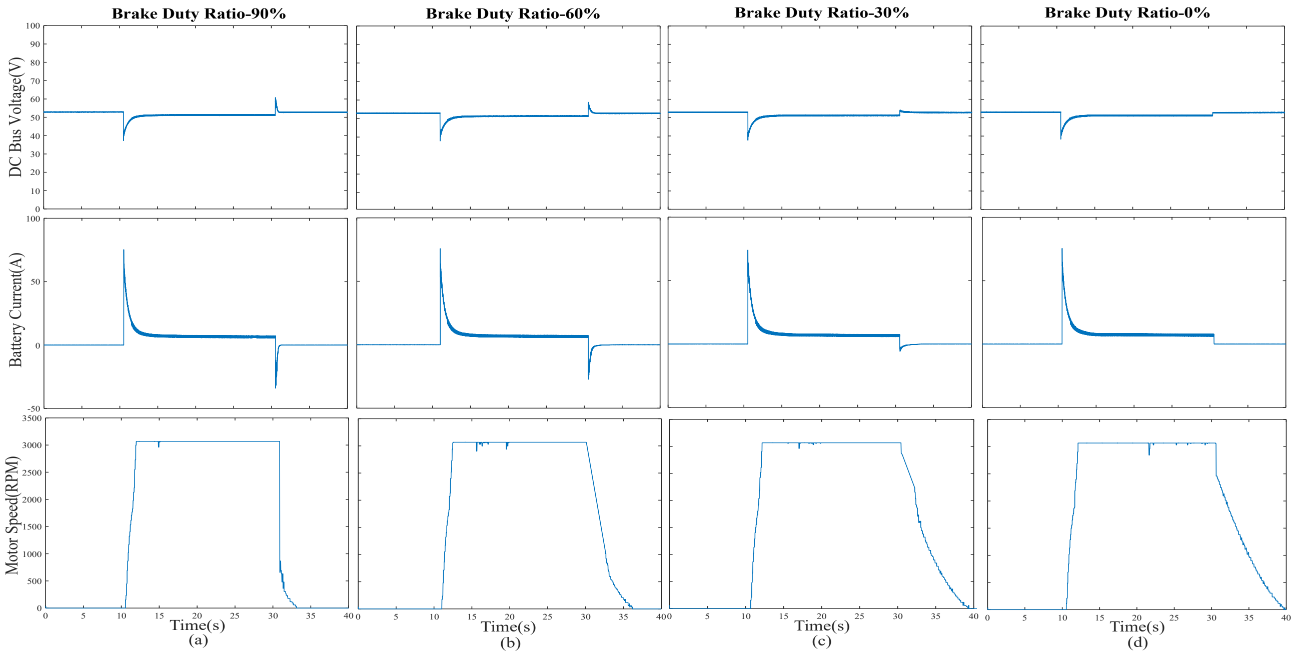


Fig. 13: Regeneration waveforms at 70% of SOC

Tab. 6: Energy recovered at 70% SOC

Motor Speed (RPM)	Energy Stored in Flywheel(J)	Brake Duty ratio	Motor Stop Time	Energy Recovered	Percentage of Energy Recovered
3100	526J	90	3S	368J	70%
		60	6S	220J	42%
		30	9S	52J	10%
		0	10S	0J	0%
2050	231J	90	3S	140J	60.6%
		60	5.5S	85J	36.7%
		30	8S	20J	8.6%
		0	8.1S	0J	0%
1000	55J	90	3S	10J	18.1%
		60	5.5S	5.J	9.1%
		30	8S	1.J	1.8%
		0	8.1S	0J	0%

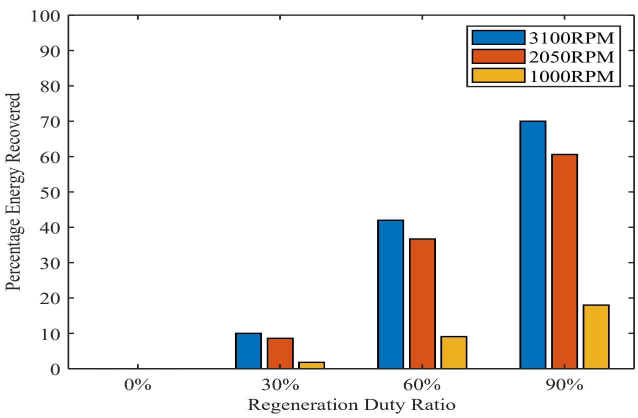


Fig. 14: Percentage energy recovered at different speeds and braking duty ratios

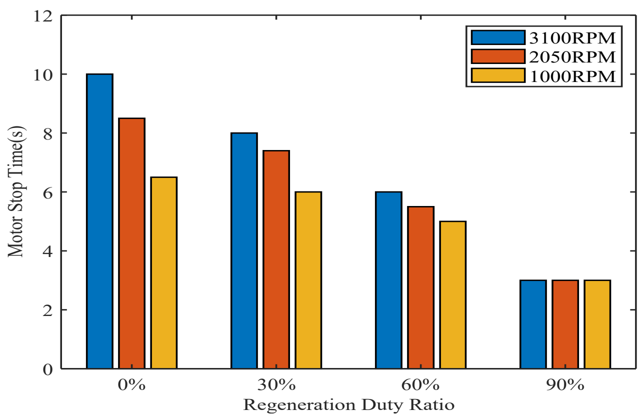


Fig. 15: Motor stop time for different speeds and braking duty ratios

Tab. 7: Energy Recovered at 96% and 99% SOC

Motor Speed (RPM)	Energy Stored in Fly-wheel(J)	SOC	Brake Duty Ratio	Motor Stop Time	Energy Re-covered	Percentage of Energy Recovered
3200	560	96%	90	3S	50J	9%
		99%	90	3S	10J	2%

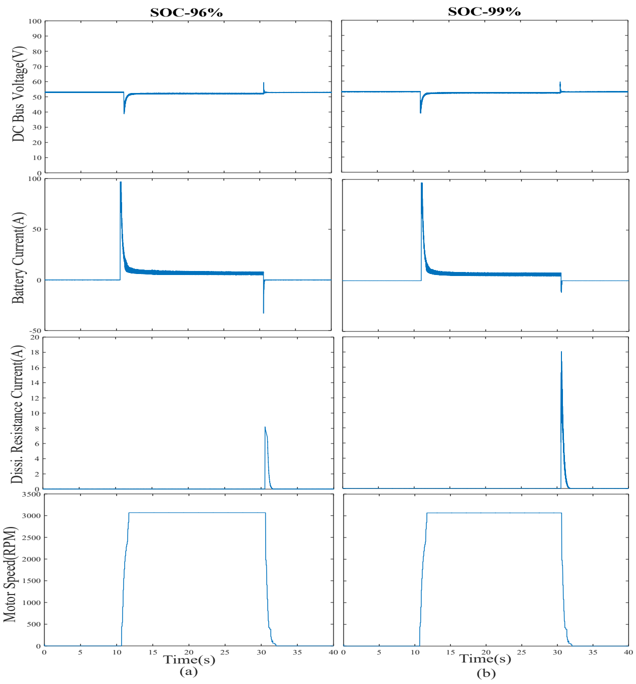


Fig. 16: Regeneration waveforms at higher SOCs and brake duty ratio-90%

7. Conclusion

When integrating an RBS with the battery in an erickshaw to extend its driving range, an EMS is essential to prevent false battery charging. To address this issue, a prototype of the proposed regenerative braking system with an actual e-rickshaw motor is built and tested successfully in the laboratory under various load conditions and braking forces. The energy recovered at SOCs below and above 95% is evaluated. This proposed method can function without extra sensors or converters, reducing circuit complexity and implementation costs.

It can be concluded that the proposed RBS is ideal for low cost electric vehicles, particularly e-rickshaws with BLDC motors, as it can recover and utilize braking energy even when the battery is fully charged or nearly fully charged, without damaging the battery

Author Contributions

P.K.A developed the theoretical formalism, performed the analytic calculations, numerical simulations and experimental validations Both D.M. and J.M. contributed to the final version of the manuscript. D.M. supervised the project..

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Appendix A WAVECT

WAVECT is an indigenous platform designed, developed, and manufactured in India under the supervision of experts from various fields.It is a versatile and compact real-time control prototyping system that includes a high-end FPGA for fast computing, a dual-core processor for control and communication, scalable embedded voltage and current sensors, a large number of PWM outputs, and high-speed IOs. WAVECT supports most comfortable and widely used model development flow, strongly harnesed by WAVECT Suit software for data monitoring, data analysis and control functions.