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Regenerative Braking Control of IM with Battery/Ultracapacitor Hybrid ESS in Electric Vehicles by using Artificial Neural Network

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ABSTRACT: The adoption of electric vehicles promises numerous benefits for modern society. At the same time, there remain significant hurdles to their wide distribution, primarily related to battery based energy sources. This review concerns the systematization of knowledge in one of the areas of the electric vehicle control, namely, the energy management issues when using braking controllers. The braking process optimization is summarized from two aspects. First, the advantageous solutions are presented that were identified in the field of gradual and urgent braking. Second, several findings discovered in adjacent fields of automation are debated as prospects for their possible application in braking control. Following the specific classification of braking methods, a generalized braking system composition is offered, and all publications are evaluated primarily in terms of their energy recovery abilities as a global target. Then, conventional and intelligent classes of braking controllers are compared. In the first category, classic PID, threshold, and sliding-mode controllers are reviewed in terms of their energy management restrictions. The second group relates to the issues of the tire friction-slip identification and braking torque allocation between the hydraulic and electrical brakes. From this perspective, several intelligent systems are analyzed in detail, especially fuzzy logic, neural network, and their numerous associations.

The values of these parameters will be decided using Artificial Neural Network (ANN). The software implementation of the project is carried out in MATLAB/Simulink. Also, an experimental setup is designed for hardware implementation of the proposed idea. Combination of four batteries is used for testing, which are controlled and operated using relay circuits.

KEYWORDS*:* battery ultracapacitor; IM regenerative braking; buck-boost converter, discharging energy distribution, ANN

I. INTRODUCTION

Regenerative braking (RB) is a crucial aspect to improve the efficiency of EV and HEV [1]. During RB, the electrical traction motor provides negative torque to the driven wheels and converts the K.E. into electrical energy for recharging the energy storage system (ESS), i.e. battery pack (BP) or ultracapacitors (UC). However, the technical characteristics of conventional batteries represent an enormous issue for the RB typology. The ultracapacitor (UC) may be a new technology that permits to present better performance in specific power than any battery and may be charged and discharged more times without performance deterioration [2]. These excellent characteristics are often utilized in combination with batteries, constituting hybrid ESS (HESS), to efficiently use the RB technique for improving the performance of EV and increasing the useful lifetime of the batteries. Many researchers have coined new strategies and designed numerous control algorithms so on reduce the
complicacy within the development of regenerative braking [3]- [5]. As stated in [3], the braking operation during a drive are often envisaged through dissipative and regenerative braking. In [4], maximum energy from wheels is extracted to the battery by operating the IM in negative slip region at different frequencies. Slip-speed control is additionally applied to break the IM as in [5].

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BP/UC HESS provides an improved solution over the stand-alone battery design in terms of improved power management and control flexibility [6]. In [7], a control strategy of DC-bus voltage and currents was presented during a battery/UC HESS. In [8], an UC-only ESS is adopted in which control strategy of DC-DC converter is applied for controlling the facility flow. In spite of the amount of publications describing the energy management strategies between BP and UC during discharging mode for both of them [6]-[7], achieving maximum discharge efficiency has little attention from researchers.
A regenerative braking control strategy is proposed to extract the K.E. from the load to charge the UC instead of the battery in HESS. Moreover, a control strategy of power flow with battery/UC HESS is also presented during the discharging mode of the adopted system. This strategy are often realized by sharing the load power between the battery and UC through a distribution factor. The optimal value of the distribution factor is determined to maximise the general efficiency. The theoretical concept of the control strategies is supported by simulation and experiments.

The vehicle researchers have made easing back system by including the pattern-setting developments. The fundamental noteworthiness of auto security and pleasing. From the eighteenth century, completing towards halting system making starts and drives forward through present day. differing types of easing back systems wont to different vehicles during the several years to handle. because the past of brakes propelled, each imaginative system was created by strategies for the impressions rummage arrangement to broaden its model. It doesn't take a logical virtue to know that it takes an enormous amount of essentialness to urge a vehicle to collect vitality. In any case, what comes upon all that essentialness once you tread on the brake? Taking everything under consideration , for many customary vehicles, the greater a part of the dynamic essentialness changed over during grinding breaking, between the brake pads and wheels, into the type of heat . Warmth for the foremost part gets transmitted unused into the world as waste, anyway not within the event that you're driving a cross variety or electrical vehicles, which may use the electrical motor to recoup in any occasion some of the engine imperativeness for reuse. All that dynamic essentialness that might have been lost for the foremost part, can generally be returned right to the battery using regenerative halting component. The strategy of recovery of engine imperativeness during breaking and its amassing called regenerative slowing down. While decelerating and braking, the vehicle's development drives the electrical motor, which changes itself to a generator mode. The wheels move the engine imperativeness by methods for the drive train to the generator. Through its rotate, the generator changes over a neighborhood of the engine essentialness into electrical imperativeness. The force made is taken care of during a high-voltage battery. The generative slowing down torque of the electrical motor, which is that the eventual outcome of imperativeness age, decelerates the vehicle. the facility transmission arranges the essentialness normally dispersed within the brakes to the imperativeness put aside during deceleration. The comparable changed over enter dynamic imperativeness to stimulate the vehicle.

II. LITERATURE REVIEW

Sreevalsan S clarified about the Different kinds of slowing mechanisms used to various cars throughout the hundreds of years grasp. As the past of brakes developed, each imaginative framework was fabricated by methods for the impressions scavenge deal to extend its model. It doesn't take a scientific genius to realize that it takes a great deal of vitality to get a vehicle to assemble forces. All things considered, for most customary vehicles, most of the motor vitality changed over during contact breaking, between the brake cushions and wheels, into the type of warmth. Warmth fundamentally gets discharged unused into nature as waste, yet not in case you're driving a half and a half or electrical vehicle, which can utilize the electric engine to recover at any rate a part of the motor vitality for reuse. All that active vitality that would have been lost in any case, can mostly be returned right to the battery utilizing regenerative slowing mechanism.

J.A.A. Hartley, as of late because of increment in carbon emanation from vehicles it has now become a significant natural concern. European car producer affiliation and European chamber together have settled on a consent to lessen CO2 outflow from street vehicles. One strategy to diminish vitality utilization and outflow from vehicles is by presenting a regenerative slowing mechanism. Utilizing this framework, we can reuse the delivered vitality by catching it. During braking by the utilization of erosion breaks the vitality is been squandered. A generator can be utilized for engrossing vehicle dynamic vitality by creating electric vitality by putting away it in batteries for later use.

Cibulka clarified that the vast majority of the trains can consolidate pneumatic braking to electrical stopping mechanism. Utilizing this framework, the dynamic vitality of the train straightforwardly changed over into electrical vitality. Probably the least difficult ways accomplished by scattering the vitality grew legitimately to resistor set on a train. Another technique is the vitality recuperation strategy in which electrical vitality sent to contact lines, which can be utilized by different trains during footing or can be put away in a battery situated on board a train.

Peter Cocona, CO2 emission is decreased in electric vehicles and they additionally sway the driving assignment. Electric vehicles have constrained fierceness which influences the excursion and decision of vehicles. Battery based electric

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vehicle has a capacity of recovering the vitality during deceleration utilizing regenerative slowing mechanism (RBS). It is executed in the brake pedal, increasing speed pedal or some of the time even both. This paper clarifies relying on the kind of framework the driver needs to adjust to the deceleration conduct utilizing RBS.

Metz, L.D. explained the 21st century has seen the brisk progression of battery electric vehicles (BEVs), which offer a perfect response for an unnatural climate change and oil subordinate inadequacies. Relative with conventional vehicles, a BEV has higher profitability of vehicle powertrain structure with the limit of bidirectional imperativeness stream for essentialness the administrators. The bidirectional essentialness stream enables a vehicle to recoup dynamic imperativeness during deceleration using a regenerative halting system (RBS) without including any additional parts.

Pagan Elli explained RBS which is a system that can change over worthless dynamic essentialness into electrical imperativeness for essentialness using the electric motor to apply negative torque to the wheels while slowing down When driving an ordinary vehicle, the potential imperativeness is typically wasted during slowing down. In any case, past what 60% of the slowing down imperativeness can be used in a common urban driving cycles. By adding motor slowing down to shape composite slowing down, the imperativeness recovery breaking point can be basically improved.

Corolla, D.A.; The control strategy structure of RBS is extensively more mind boggling than a normal easing back component plan. In late examinations of RBSs, analysts worldwide have proposed a movement of promising assessment on RBS method plans. In the impact of confining components, for instance, the battery\'s state of charge (SOC), the characteristics of the battery and the motor of a blend vehicle RBS, road managing, and security were looked into.

Juan J.C.A. developed a fluffy RBS method using segments like tire powers, vehicle speed, and road grasp for estimation, while considering the wheel slip and slowing down security. These works applied smoothed out slowing down cycles as the essential information. Regardless, certified world-based execution relationships of regenerative slowing down methods, that can fulfil the as of late referenced essentials, are every so often finished. Consequently, this assessment is proposed to address this deficiency.

Justin clarified about the strong blue bend in the figure speaks to the "perfect slowing down power dissemination" bend. The structure of the slowing down dispersion systems follows these two bends, to understand a palatable harmony between slowing down security and vitality recuperation proficiency. To comprehend the proposed slowing down techniques and slowing down execution concerns, a fundamental, consistent stream diagram. At the point when the pedal moves, the stopping mechanism investigations the brake wellbeing circumstance, and follows the picked slowing down methodology predictable with different guidelines. Any event of a wheel lock triggers the ABS.

Xin Jing clarified the perfect back-EMF, stage flow, and created torque profiles of PM BLDC engine are a finished substitution cycle crossing 360º electrical comprising of six equivalent interiors. The switches S1 to S6 are worked during a grouping utilizing a negative criticism circuit upheld position got from the rotor position sensors like lobby impact sensors. To control the torque, which is created by the engine, the control by the inverter circuit. The procedure of regenerative slowing down is appeared by the arm under the IGBT connect whose exchanged developments relate to the working module of the engine.

III. TRANSFERRING OF BRAKING FORCE

The regenerative slowing down of electric vehicle, mostly the slowing down power is front wheel slowing down power and back wheel slowing down power .in two pieces of front wheel slowing down power are front wheel frictional slowing down power and regenerative slowing down power. The front and the back wheel slowing down power portion technique in the electric vehicles is $z<0.1$, the aggregate slowing down is all borne by the drive and same occasions front wheel not engaged with the slowing down of the electric vehicle. At that point $< z < 0.7$ the slowing down power can be dispensed by the electromechanical composite brake.

A. Components Of Regenerative Braking System:

• In each vehicle, while utilizing a Regenerative slowing mechanism, it consists of an actuator and a vitality stockpiling gadget, individually. And furthermore found that the controlling unit is additionally part of the Regenerative slowing mechanism.

• In electric vehicles, an actuator is an electric machine which is otherwise called Engine or Generator and the got vitality put away in the battery which is the force wellspring of the vehicle.

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While utilizing this sort of slowing mechanism, the regular actuators are electric machines, water powered siphon engines, CVTs (constantly factor transmissions) and air-controlled engines. And furthermore, vitality stockpiling gadgets are Batteries, ultra-capacitors, flywheels, and metal aggregators.

In this Regenerative slowing mechanism, there is a slowing down controller that builds up the association among actuator and vitality stockpiling gadget. And furthermore, it controls the general procedure of the actuator, observing wheel - speed, computing slowing down torque and moving the created power into vitality stockpiling gadget during slowing down. The slowing down controller gets data from the driver that it acquires through the pedal position and makes an interpretation of it to genuine machine prompts.

B. Battery System In Electrical Atv

The brake control methodology framework can be arriving at the battery subsystem. In the subsystem positive force released the battery framework and negative force charges on the battery .the presentation of the battery can be set by the underlying worth of SOC in 90%. The release square relies upon the condition of the charge level. At that point from interest force and most extreme voltage empowered the SOC, at that point compute the current and flexibly it to the engine. At that point most extreme measure of current can be dealt with in the engine. This current is again restricted and most extreme current ability of the generator. No current is pulled back or set back during this stage. The lithium-particle battery can be utilized the battery framework.

C. Main Use Of Ultra-Capacitor:

• Ultra-capacitor assumes exceptionally fundamental job in the entire framework, with the goal that the new advancements have the such capacities to control them. In the ultra-capacitor framework, the significant substance are the DC-DC converter base on the protected entryway bipolar transistor [IGBT], smoothing aluminium inductor Ls, ultra-capacitor, and battery pack.

• During increasing speed, the capacitor voltage of ultra-capacitor allowed to liberate from stuffed rate charge to 33% of its ostensible voltage. During deceleration, the vitality of a capacitor which is discharged during increasing speed period is improved back and energize the ultra-capacitor.

Ultra-capacitor is for the most part utilized on the grounds that it stores up multiple times more vitality as assess to electrolytic capacitor as appearing in figure 6. Ultra- capacitor likewise improves the transient execution in EVs, additionally increment life expectancy of batteries. Ultra-capacitor gives extra flexibly to the electric vehicles and furthermore broadens the separation

IV. SERIAL STRATEGY

Serial regenerative braking is based on a combination of friction-based adjustable braking system with a regenerative braking system that transfers energy to the electric motors and batteries under an integrated control strategy. The overall design is to estimate the deceleration required by the driver and distribute the required braking force between the regenerative braking system and the mechanical braking system. Serial regenerative braking could give an increase of 15-30% in fuel efficiency. It requires a brake-by-wire system and has more consistent pedal felt due to good torque blending capability.

V. SYSTEM DESCRIPTION

The system is composed to 3-phase IM, 2-level inverter, Ultracapacitor, Battery-Pack, and a controlled DC link by DC-DC chopper, as shown in Fig. 1. The IM is controlled in motoring and generator modes. However, this paper concerns only the regenerative operation at braking periods. The DC-DC chopper works at buck-boost operation. A battery with 450Vdc is used and the voltage of the DC link is enhanced by two parallel capacitors (each of 4700 μF). The internal resistance of the BP is estimated as 0.1Ω. Details of used UC are listed in Table I. The UC module and lithium batteries are coupled to DC-bus through a buck-boost converter, which ensures the energy exchange between UC, BP, and the load.

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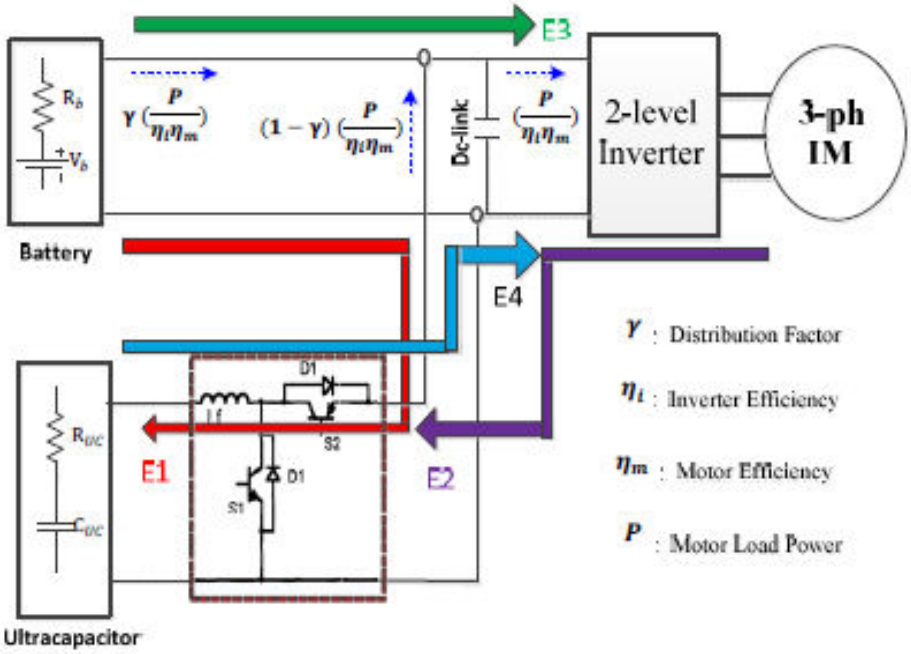

Fig. 1. System description with power flow

NEURAL NETWORKS

Artificial Neural Networks (ANN) Architecture implies how neurons are arranged in the form of layers and the type of interactions between the neurons. Architectures of neural networks are closely related to the training/learning algorithm applied on these networks. The various architectures of neural networks are represented in Fig.2.

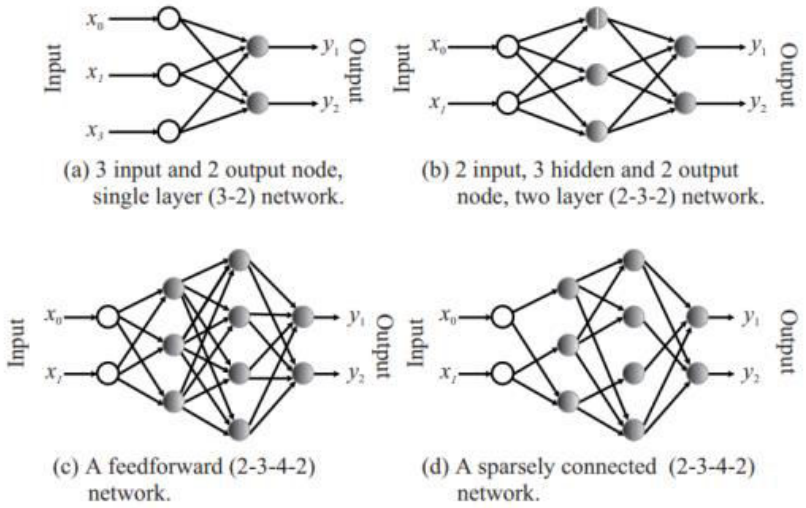

Fig. 2. Various architectures of ANN

Out of the various types of neural networks, feed forward neural network is the type preferred in this design. As the name suggests, the input data is fed in the forward direction through the network. Each hidden layer accepts the input data, processes it as per the activation function and passes to the successive layer. The data should not flow in reverse direction during output generation otherwise it would form a cycle and the output could never be generated. Such network configurations are known as feed-forward network. The feed-forward network help in forward propagation. At each neuron in a hidden or output layer, the processing happens in two steps: 1. Pre-activation: It is a weighted sum of inputs i.e. The linear transformation of weights w.r.t to inputs available. Based on this aggregated sum and activation function the neuron makes a decision whether to pass this information further or not. 2. Activation: the calculated weighted sum of inputs is passed to the activation function. An activation function is a mathematical function which

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adds non-linearity to the network. There are four commonly used and popular activation functions — sigmoid, hyperbolic tangent(tanh), ReLU and Softmax.

VI. WORKING PRINCIPLE

Right when voltage is applied to the data shaft, wheel starts turning clockwise way. This clockwise development is also moved to the second shaft through the arranging pulley and from now on the sprocket to the post 3. We are using Timing pulley since its viability is 99.99% in this manner, the grinding hardships are overlooked. Development which is transmitted to the sprocket shaft is passed on to the third shaft from which flywheel is related. The Movement of the shaft is transmitted to the flywheel and it is related with 1:1 mechanical assembly extent gears with the dynamo. The dynamo is used to change over the rotational essentialness to the mechanical imperativeness. Essentially, its work is to store the imperativeness. Right when we apply the brake, the motor continues to work yet the wheel gets stopped and henceforth the sprocket shaft also gets ended anyway the flywheel keeps turning. The settling time of the induction motor after the break is applied is 0.75-1.25 second. That is all the breaking process is takes place with in 0.5 second.

VII. RESULTS

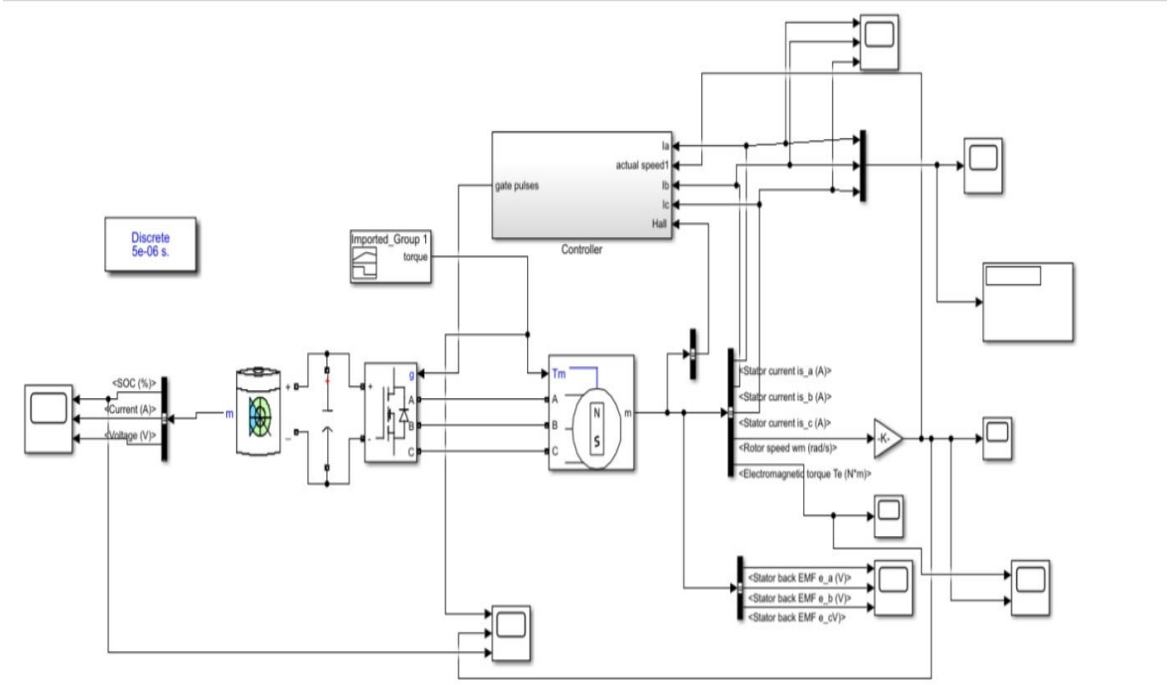

Fig.3.Simulation

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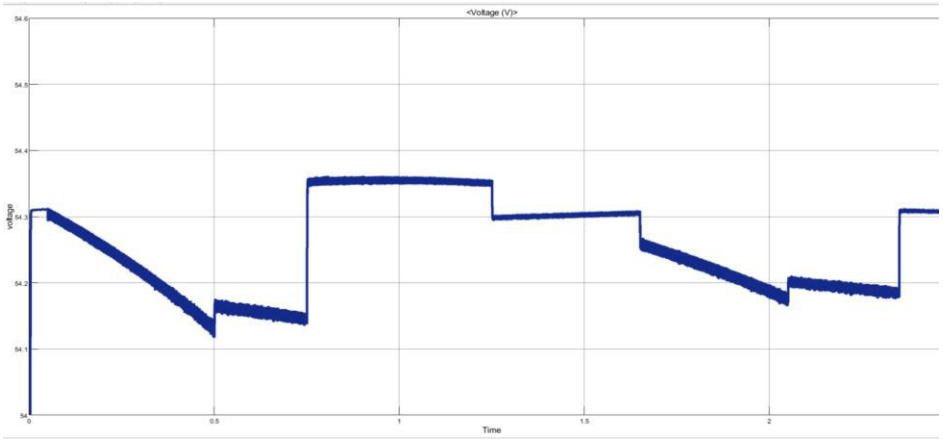

Fig(a): Back EMF

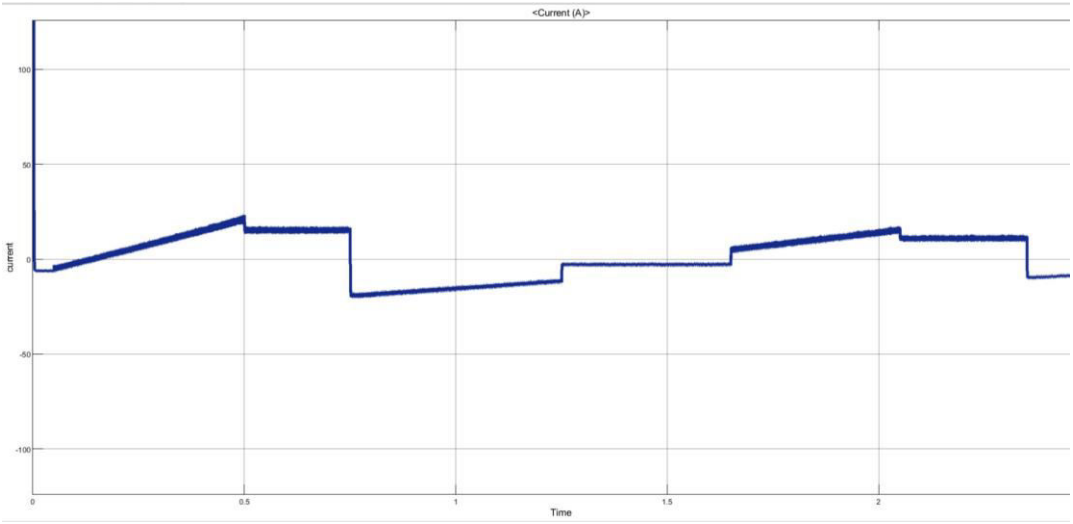

Fig.(b): Current

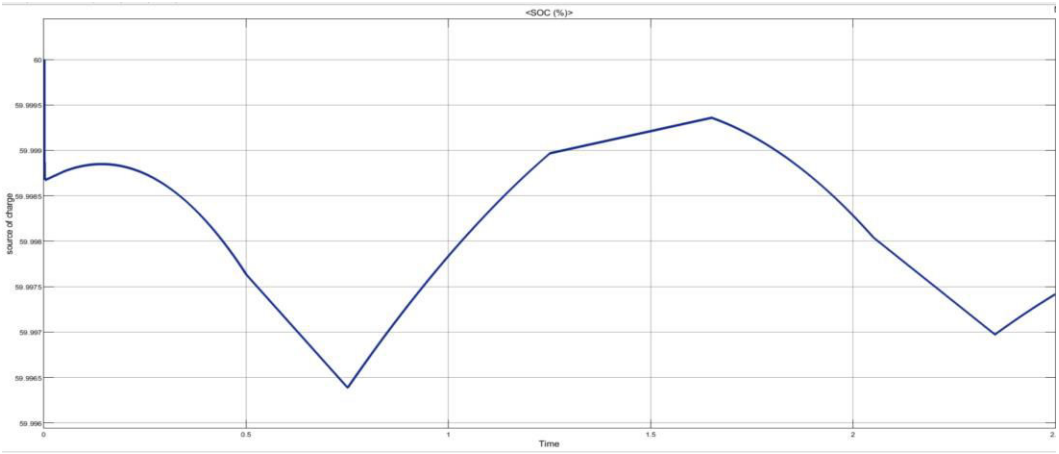

Fig.(c): Source of charge

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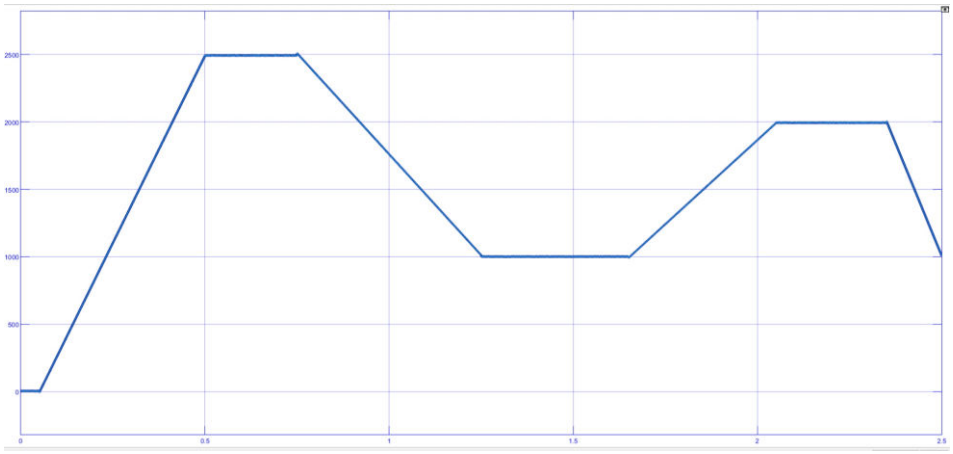

Fig.(c): Speed (here we see Settling time)

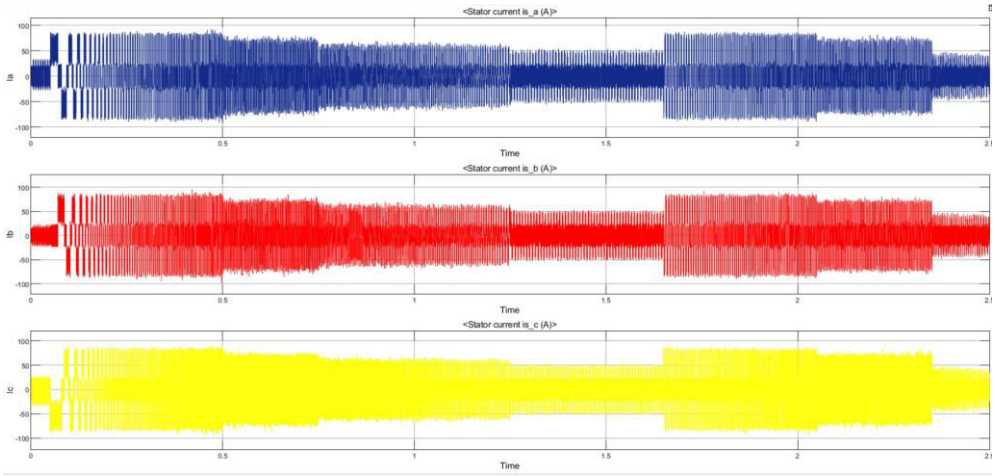

Fig.(d): Current Ia, Ib, Ic

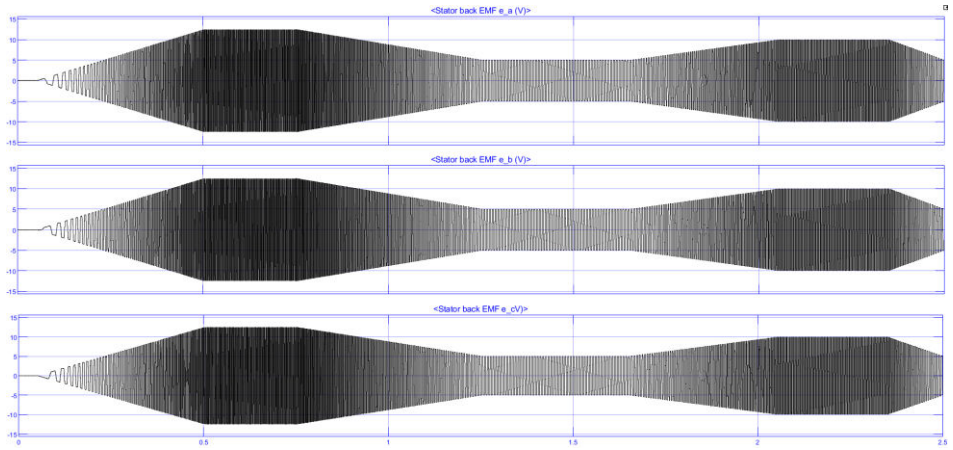

Fig.(e): Back EMF Va, Vb, Vc

Fig.4. Experimental results at braking test

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Table 1: Comparison of PI and ANN

Parameter		PI	ANN
Electro Magnetic Torque		-3.367 NM	0.75 NM
Back EMF	V_a	-3.902 V	5.006V
	V_b	5.006V	-2.396V
	V_c	-5.006V	-5.006V
Current	I_a	8.47A	8.95A
	I_b	-36.37A	-4.048A
	I_c	27.9A	-4.902A

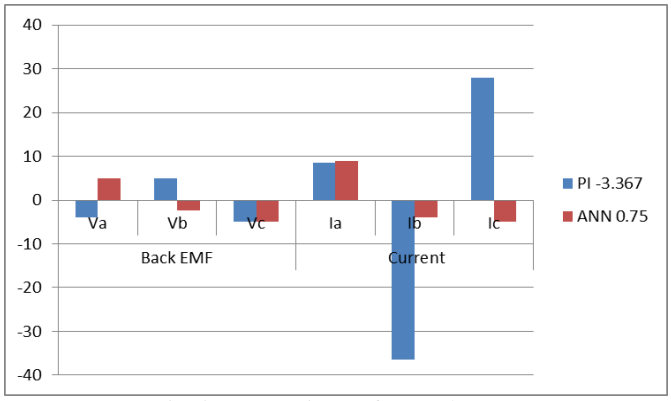

Fig.5. Comparison of PI and ANN

VIII. CONCLUSION

This paper presented a successful control method for speed control of IM at braking times. Through the experiments, the IM is controlled to regenerate its power to its DC-link bus. This extra energy at braking is exploited to charge the UC for increasing the efficiency of the system. An impact strategy for discharging mode of both UC and battery is presented. The efficiency of power flow could be improved by increasing the distribution factor. In regenerative braking, with the proposed control method, the kinetic power is retrieved within the UC rather the battery. The whole system is integrated and charging of the UC at braking and therefore the effectiveness of the distribution factor to obtain maximum efficiency are validated by simulation. ANN technique has been used to obtain gain parameters of controllers. The simulated results of an braking system are compared with and without controller and further between the distinctive sorts of controllers. The output response of ANN Algorithm is better as compared to PI controller.

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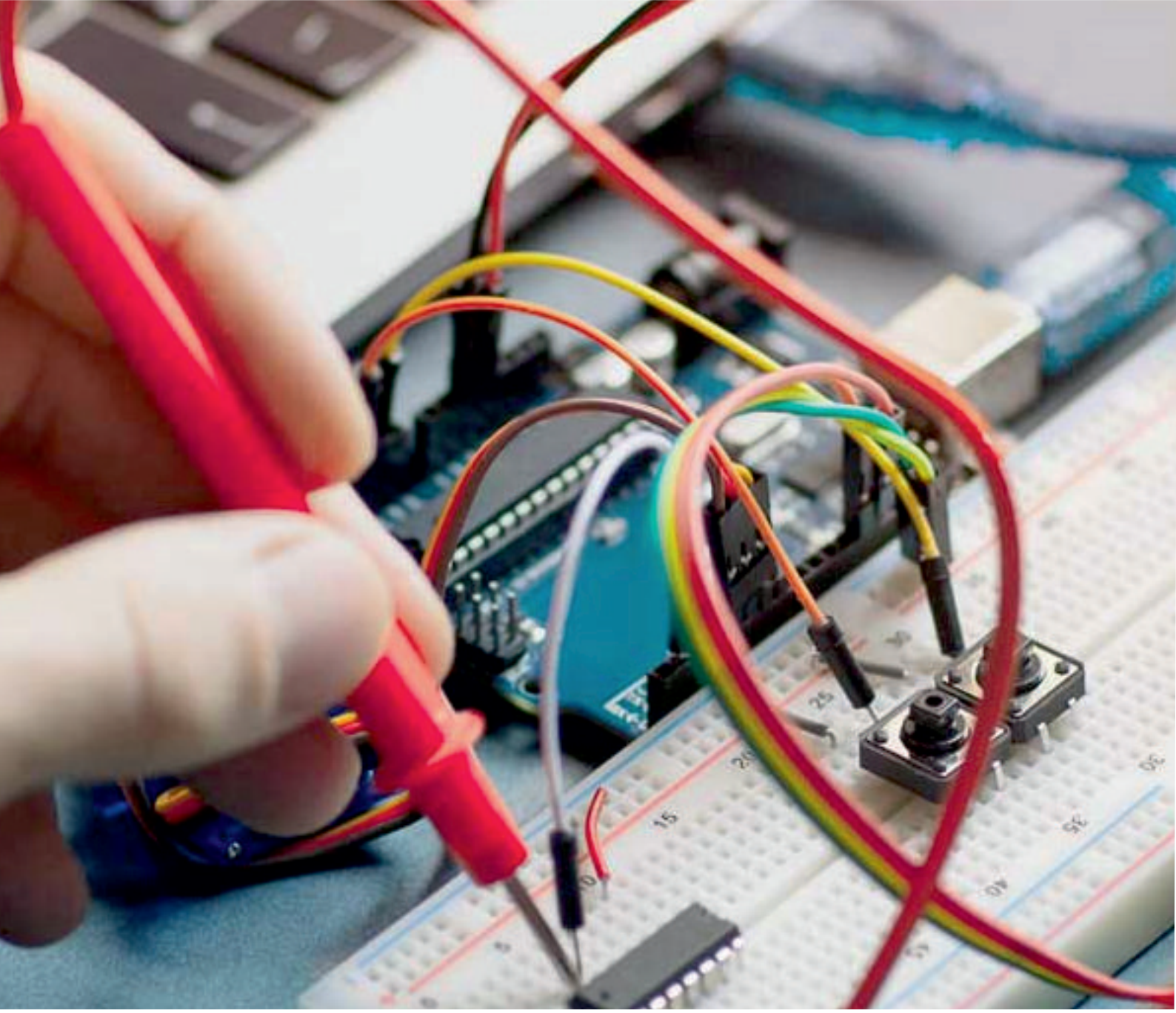

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