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SPEED CONTROL OF ELECTRICAL VEHICLE USING BLDC DRIVE WITH FUZZY LOGIC

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ABSTRACT: Electrical motors specially Brush Less Direct Current (BLDC) play very important role in Electric vehicles. It's Efficiency and Reliability is the key feature for the development of motor drives, since it indirectly controls the mechanical output required. The permanent magnet rotor of inverter fed BLDC motor generates a trapezoidal back EMF waveform in the stator windings. In this research, Fuzzy Logic is utilized to control the speed of a BLDC motor. Fuzzy logic has a higher ability to reject disturbances and has a smaller overshoot in speed response of the motor. The simulation & design analysis of the proposed system is done using MATLAB version 2021a, also the simulation results of fuzzy controller of proposed system are compared with normal PI controller.

Index Terms **- BLDC motor, Fuzzy logic, speed control, Hall Effect Sensors**

I. INTRODUCTION

Electrical vehicles are becoming best option nowadays for these costly fuel inefficient vehicles. Hence electrical vehicle will be a future for automobile industries. In past few decades, BLDC motor was widely used in many real world applications [1]. The use of BLDC motor has been increased and becoming the important parameter in automation, robotics and other industrial applications [3]. There are various advantages of using BLDC motors such as high reliability, good torque to inertia ratio, better performance; also it has simple construction [5]. BLDC motors are same as Permanent magnet synchronous machine. As the name suggests, BLDC motor does not have brushes so the commutations happens electronically. Hence BLDC does not have sparking problem. Apart from this, there are other main highlights of BLDC motors such as low rotor losses, less noise[1] and higher efficiency with wide speed ranges makes a BLDC drive perfect for the application of Electrical vehicle[6].

In this study, fuzzy logic has been utilised to control the speed of the electrical vehicle with fewer variations. In 1965 Lotfizadeh coined the phrase "fuzzy." Then It has been used in a variety of fields, including control theory and artificial intelligence. Basically this fuzzy logic controller is used due to various reasons such as flexibility, Accuracy and precise values of those output parameters. There is no need to have an accurate mathematical model required for the fuzzy on the operation of system. For the conventional controllers there is an overshoot in the speed control whereas for fuzzy controller there is very less overshoot compared to other controllers. The use of fuzzy makes the system capable to understand various conditions and to give the best suitable operation for the performance.

In this paper, an attempt is made to control the speed of BLDC motor for electric vehicle. Proposed model is simulated and tested on MATLAB/simulink platform and results are validated. The simulated results have the different waveforms for various parameters like Speed, torque, back emf, fuzzy results etc.

II.BLDC MOTOR DETAILS

The main and most important part of the Electric vehicle is motor. So there are many terms and calculations need to be carried out for the modelling purpose. So for simplicity the motor is considered to have perfect trapezoidal phase back emfs of trapezoidal waveforms[7] which has a 120^o platue and which will be having the quasi-square wave stator currents. PMSM and BLDC are having same construction and parameters. In working of BLDC motor, as it has three phase windings, firstly say winding A is energised. So this energization creates south and north poles. Stator S pole will repail S pole and attract N pole. So after phase A, phase B of motor is energised and then Phase C is energised and hence the rotation of motor takes place.

Stator of a Brushless DC motor contains mainly the laminations which are made up of steel. In the slots of the motor, steel and windings are put. Semiconductor control is used to manage the stator current in order to get maximum torque at a particular speed. Stator has three phase windings. To make an even number of poles, these windings are dispersed around the periphery. Generally most of the BLDC motors are connected in star connections. So the stator windings are of two types namely sinusoidal and trapezoidal.

Rotor design/construction varies from 2 to 8 pole pairs with alternate South and North Poles. Rotating of rotor is completely dependent on current produced at stator, as the stator current exerts a force on the rotor, it rotates at a specific speed. As a result, changing current across the stator will control speed. Rotors of BLDC are made up of permanent magnets. The magnetic material is selected according to the magnetic field density in the rotor of the motor. Generally Ferrite material is used as it is less expensive but only disadvantage is that it has low flux density. These magnets provide higher torque and improves size-to-weight ratio[5].

III. CLOSED LOOP CONTROL OF PROPOSED SYSTEM

In case of the BLDC machine internal feedback is provided with the help of shaft position sensors (Hall sensors), which track shaft position and give signal to the drive electronics. The rotor electrical angle (θ) indicates the rotor's spinning location in the plane of 360^0. This actually senses the actual position of rotor. Based on the rotor angle position, the hall sensors (H1, H2 & H3) are mounted on the shaft. This is done for the generation of signals for power semi-conductor to trigger the switches. The BLDC motor is driven by these pulses, which are fed to a DC/AC Converter.

As illustrated in Fig. 2, H1, H2, H3 these three are digital outputs which are received from the rotor positioning sensors i.e. the Hall effect sensors. The shaft position sensors offer information about the actual or the current position of the rotor [4]which is very important and used to estimate the conduction of the each and every phase winding. The three symmetrical phases, phase A , B and C in which all phenomena are analogous at intervals of 120^0, with 60^0 being the overlap time period. During this interval a phase has both polarities. For the interval 120^0 - 180^0 (i.e. overlapping period), North Pole is moving away and South Pole enters phase A, resulting in a steady decline in induced the EMF, yet for the positive induced EMF, current is also positive, which results in positive power and therefore it gives a positive torque value[2].

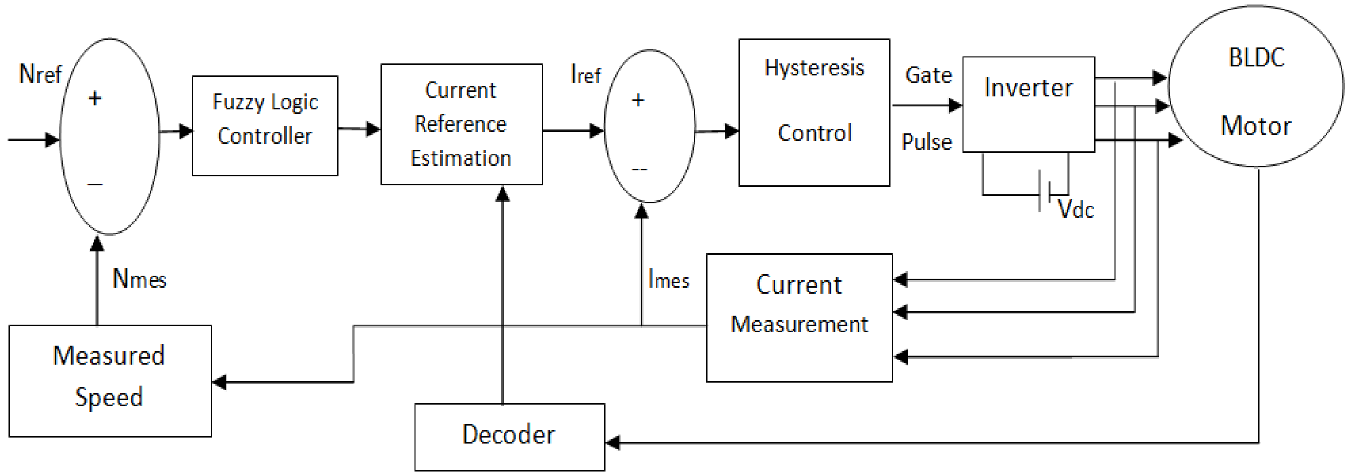

Fig.1 Internal Closed loop control

The block diagram for a closed-loop BLDC motor for electric vehicle is shown in Figure 1. The reference speed is compared to the motor's actual speed, and the resulting error is increased/magnified. The approximated torque is generated by this magnified error, which further generates the reference current. The implementation of logical operators yields the three phase unit signals (I_{abc}). Because current must be quasi-rectangular to achieve the trapezoidal EMF, The load current of BLDC motor drives is controlled by forcing it to follow a reference current within a prescribed hysteresis band, which is achieved through the switching action of a VSI.. The inverter power semi-conductor switches are activated using the hysteresis comparators' produced signals. The commutation process in BLDC motors is controlled electronically. The rotation of the BLDCM is dependent on energizing the stator windings in the correct order, with Hall sensors in the stator sensing the rotor position at 60^0 intervals. A signal (high/low) indicates the North or South Pole passing near that particular sensor when rotor poles (magnetic) cross the sensors. The combination of these three Hall sensors can thus determine the dominant sequence which is required for proper commutation. Using a decoder circuit, the hall signal is transformed to switching pulses and sent to the VSI. Table 1 shows the switching states for each combination of Hall sensor signal state. It may be stated that while two switches remain on at the same time, conduction loss is reduced, resulting in a 120^0 conduction mode of three-phase VSI. [2] Figure 2 illustrates the power circuit topology.

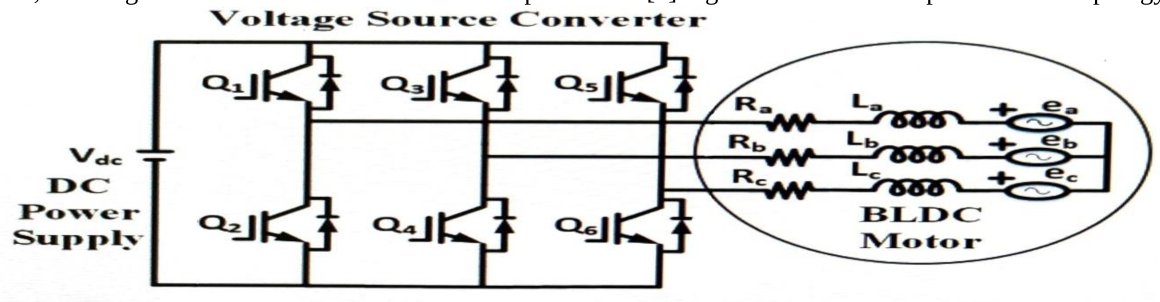

Fig.2 Power circuit topology

Table1.Switching combination of the position sensors

Modes	**Active Interval**	**Position Sensors**			**Decoded Signals**	**Active Switches**	**Phase Currents**		
		H1	H2	H3			**A**	**B**	**C**
Mode 1	0 - 60	1	0	0	1 0 -1	Q1 Q4	+	-	0
Mode 2	60 -120	1	1	0	0 1 -1	Q1 Q6	+	0	-
Mode 3	120-180	0	1	0	-1 1 0	Q3 Q6	0	+	-
Mode 4	180-240	0	1	1	-1 0 1	Q3 Q2	-	+	0
Mode 5	240-300	0	0	1	0 -1 1	Q5 Q2	-	0	+
Mode 6	300-360	1	0	1	1 -1 0	Q5 Q4	0	-	+

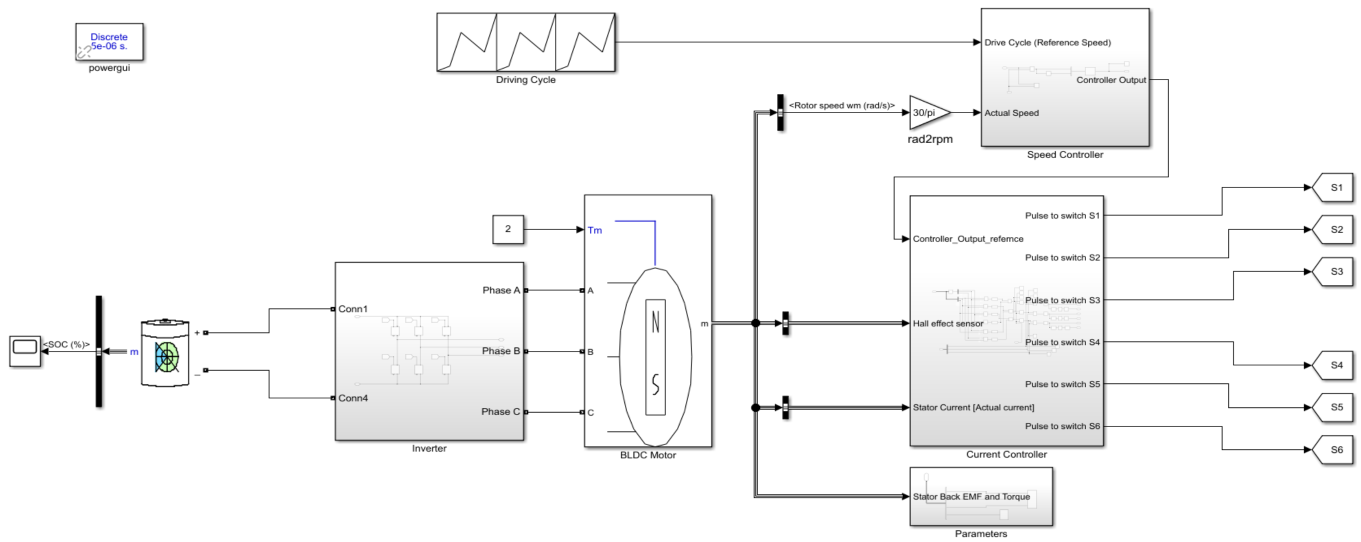

Fig.3 Proposed Matlab simulation system

IV. FUZZY LOGIC

Instead of the commonly used 1 or 0 boolean logic, fuzzy logic is actually based on the principle of 'degree of truth.' In the domain of control systems, fuzzy logic is the most successful and important technologies used in the different applications. This is due to the fact that it provides ideal solutions for its numerous applications. Fuzzy logic is capable to create exact solutions when it is provided with just approximate knowledge. It's also a superset of Boolean logic that can deal with the truth of partial truth.

The fuzzy logic controller (FLC) is essentially a rule-based controller. It's a control algorithm based on the linguistic control method. The distinction between fuzzy logic and other controllers is that conventional controllers need complicated mathematical calculations, whereas fuzzy logic attempts to account for human understanding without using a mathematical model, making it more applicable in a variety of circumstances.

V. INTERNAL WORKING OF FUZZY

The controller's very initial block, which transforms or converts each piece of degree of membership input data into one or more membership functions. Aside from that, it matches the incoming data to the defined rule base's conditions. The fuzzification process includes functions such as measuring the values of input variables, transforming input data into relevant linguistic values, and executing a scale mapping that transfers the range of input variables into corresponding universes of discourse.

The term "rule base" refers to a collection of different rules. As a result, these rules are written in the IF-THEN format. The if-side is referred to as the condition, and the then-side is referred to as the conclusion. The control signal is made up of reference error and error change. It consists of application domain knowledge. This is made up of a data base and a set of linguistic control rules. The information gives helpful definitions, which are then used in FLC to build linguistic control rules and fuzzy data manipulation. The domain experts' control goals and policies are also defined by the rule base.

The kernel of an FLC is the fuzzy inference engine. This inference engine is capable of inferring fuzzy control actions through fuzzy implantation or making human decisions based on fuzzy ideas..

Defuzzification is done to convert the inference mechanism's conclusions into real-world inputs for the process. As a result, in Defuzzification, all of the activated actions are integrated and turned into a single non-fuzzy output signal [5].

VI. PROPOSED SYSTEM

In this application the reference speed is set to various values at different points of time. Here New European Driving Cycle (NEDC) is applied to electrical vehicle. So the motor of the electrical vehicle has to follow the speed which is set in this cycle. The reference speed and measured speed of the motor is compared and the error is generated. This error is given as input to the fuzzy logic controller.

Fuzzy controller is already defined with different rules so that the controller has enough information about the different situations which are occurring during actual operation of vehicle. By controlling the amount of current actually torque response is get improved this is also because of BLDC and fuzzy rules. Improved torque response gives stability to vehicle and also tries to improve the overall efficiency of vehicle. The fuzzy rules are given below in table.

Table 2 Proposed fuzzy rule base

E/ΔE	NB	NS	VC	PS	PB
NB	VL	L	VS	S	S
NS	L	L	VS	S	S
VC	S	S	S	VL	VL
PS	S	VS	L	VS	VL
PB	VS	VS	VL	L	VL

The terms used in this table are as Negative Big(NB), Negative Small(NS), Very Close(VC), Positive Small(PS), Positive Big(PB) and Very Large(VL), Large(L), Small(S), Very Small(VS).

These rules are defined in fuzzy tool box for the controller. The perfect range for the accurate output of the fuzzy controller must be decided by proper observation. The overall operations of the fuzzy occurs in steps such as Fuzzification → Inference engine → Rule base → Defuzzification

VII. RESULT

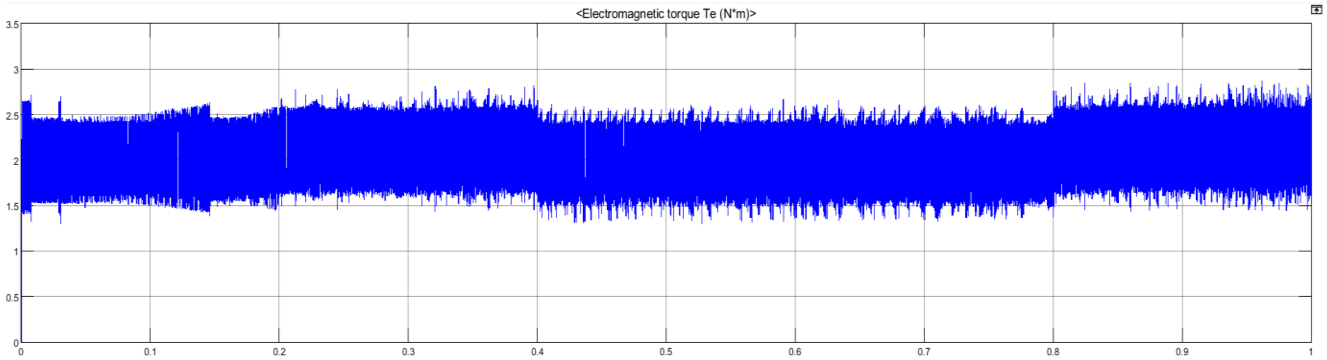

Fig.4 Torque response of fuzzy logic controller

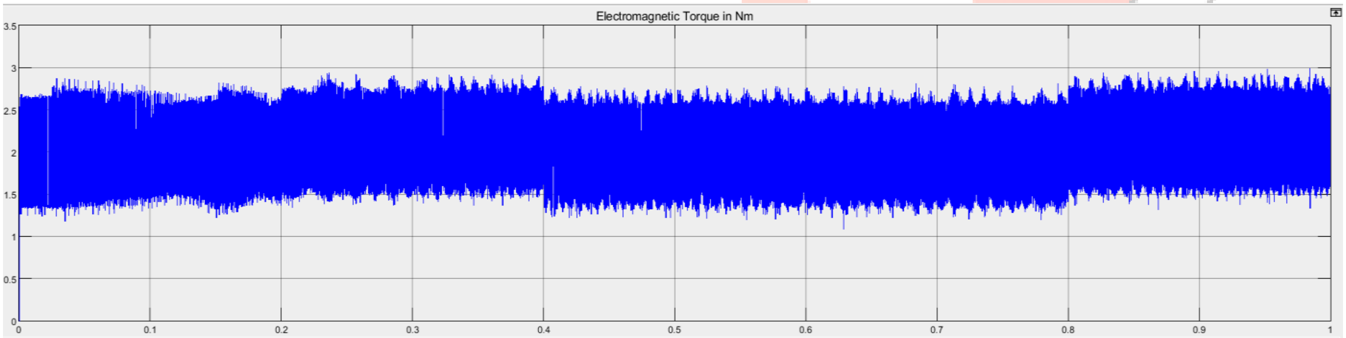

Fig.5 Torque response of Normal PI controller

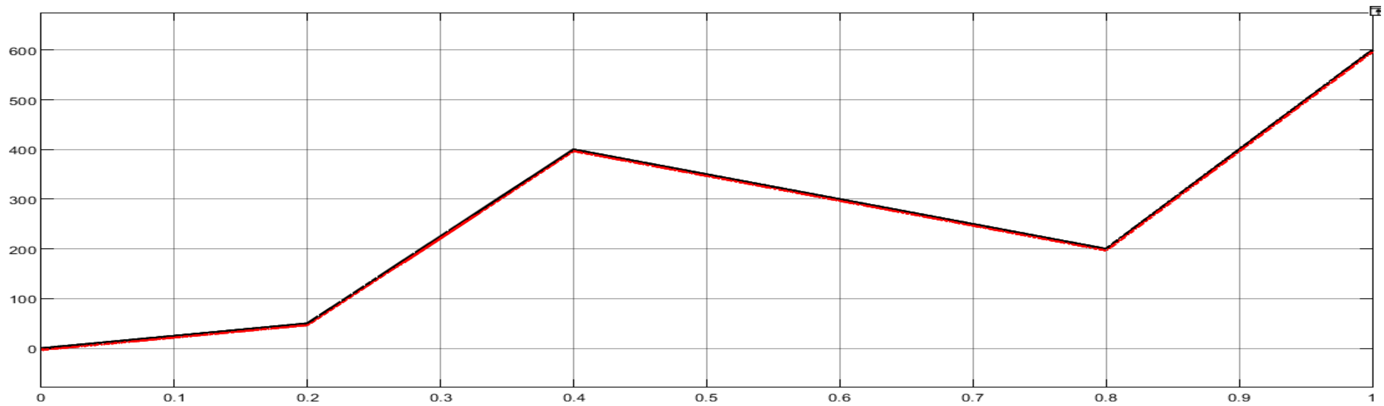

Fig.6 Waveform of Reference speed and actual speed at different speeds

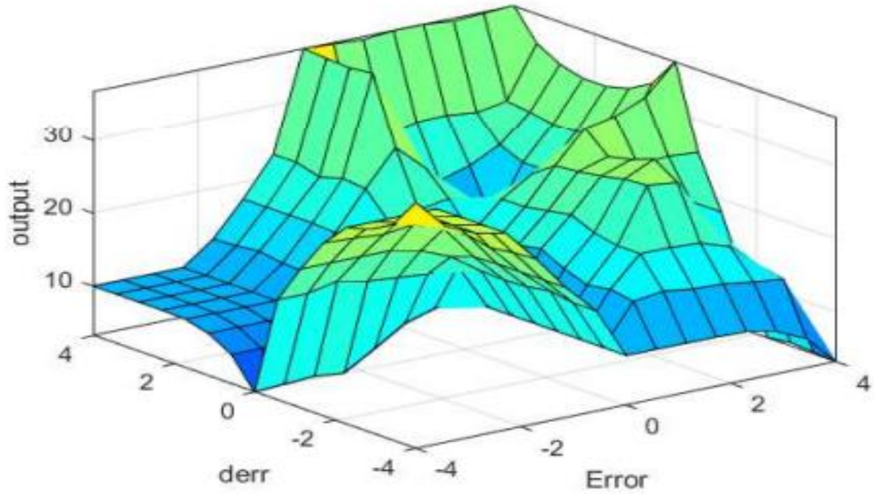

Fig.7 Surface view of fuzzy rules

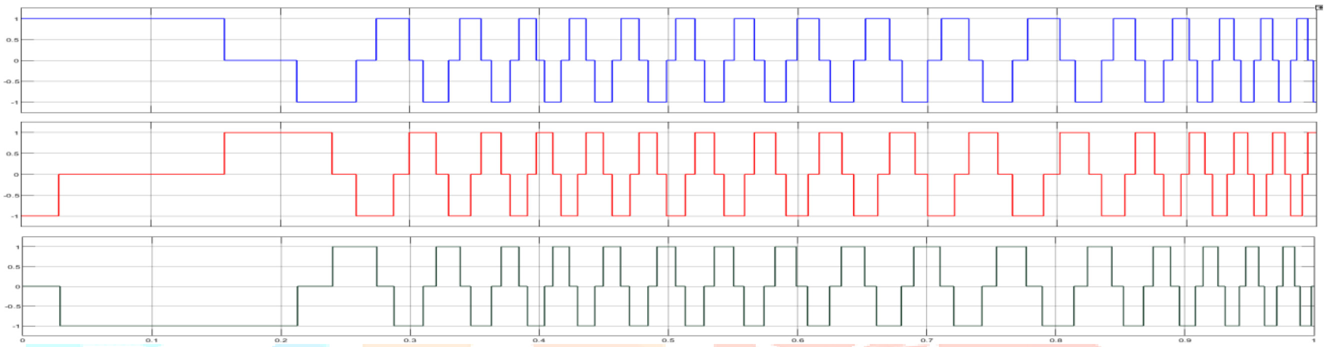

Fig.8 Hall effect sensor outputs

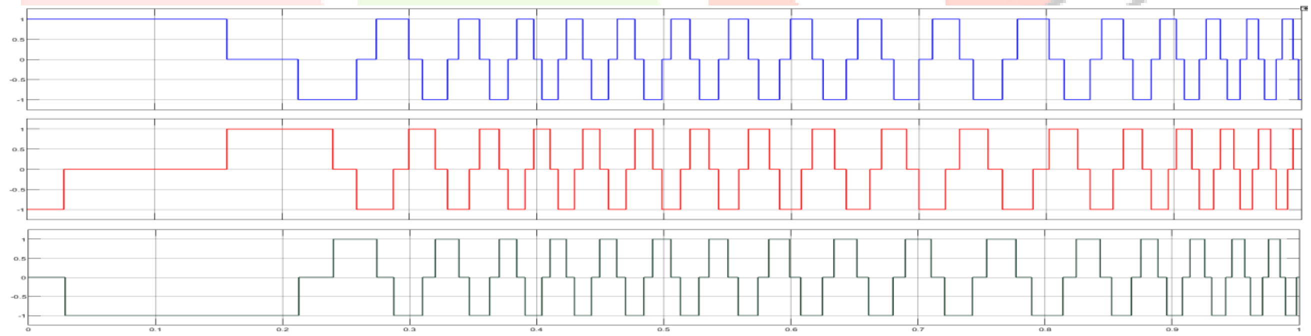

Fig.9 Back emf waveforms

VIII .CONCLUSION

BLDC Motor applications are rapidly expanding in a variety of fields these days, also in electric vehicle it is used because of the enormous advantages such as rugged construction, higher efficiency, simple control, etc. A comparative study has been discussed between the Fuzzy Logic & PI controller used on the MA TLAB Simulink tool for the speed control of a Electric vehicle. This shows that the stability for the Electric vehicle has been improved as the torque response and the fluctuations in torque have been improved. Other adaptive and demanding augmentation techniques, such as artificial neural networks or neuro-fuzzy implementations, could be considered in the future.

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