Simulation of BELBIC in BLDC Motor Drive System for Electric Vehicle

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Abstract

Emotional learning is one kind of learning strategies depends on emotional estimations that assess the impact of external stimuli on the ability of the system to function effectively in the short term and to maintain its long-term survival prospects. The controller which is based on the emotional dealing trick in the brain is called BELBIC. The intelligent control is inspired by the limbic system of the mammalian brain. In this paper Matlab/Simulink, the simulation model of the complete system is built to control the speed and torque of the machine. In a speed loop, BELBIC is proposed as a speed controller in this paper. In the BLDC drive system Speed and torque performance of the machine is enhanced by the BELBIC controller compared to conventional PI controller with minimum processing time.

Keywords: *BLDC motor; speed controller; BELBIC.*

I. INTRODUCTION

Brushless DC Motors (BLDC) motors fed by PWM inverters are widely used for industrial applications, especially servo drive applications, in which the constant torque operation is desired. In traction and the spindle drives, on the other hand, a constant power operation is desired. The inherent advantages of these machines are light, small, simple mechanical construction, easy maintenance, high reliability and high efficiency. The drive system BLDC was controlled using a PI controller due to its simplicity. The cutaway view of a brushless DC motor is shown in Fig. 1. The PI controller, however, cannot provide good performance in both conditions and load transient disturbances. Several researchers have studied the design of BLDC systems Cruise control with adjustable speed to improve their transient responses of the load disturbance rejection capability, monitoring capacity and robustness. [1]

This best motor response also allows constant speed, instant speed regulation and a quieter drive system [2]. Speed torque characteristics of BLDC motor are shown in Fig. 2. From the characteristic curve, it is clear that it has wide constant torque region [6]-[7]. Design, implementation and performance analysis of fuzzy logic controllers (FLC) for a variety of applications such as DC servo motor, BLDC motor, gas turbine factory and servo systems are presented in [8].

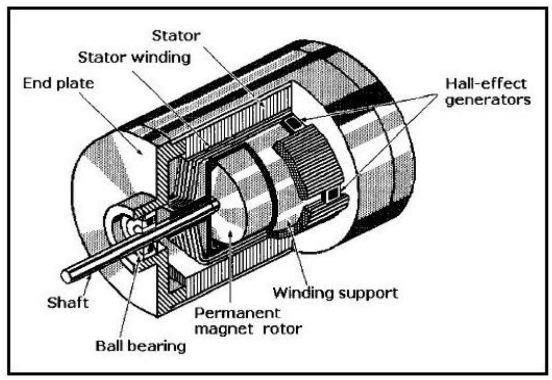

Fig 1: Cutaway view of a brushless DC motor

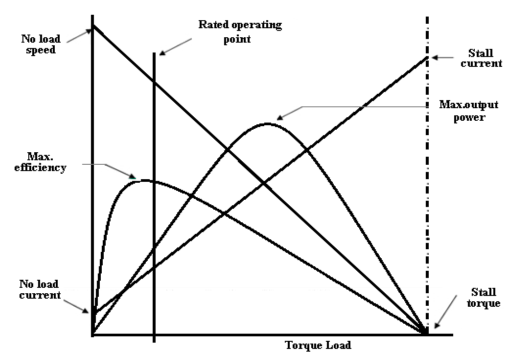

Fig 2: Characteristics of BLDC Motor

Naseeeruddin Mohammed et al. [9] studied the BLDC motor speed control using the PI controller. Tashakori et al. [4] Nikola Milivojevic et al [6] analyzed the engine speed control BLDC using PI controller with the PWM switching modes. Purna Chandra Rao et al. [9] introduced the PID controller for the BLDC motor speed control in various loading conditions. Sathyan Anand et al. [10] discussed the PID controller based BLDC motor control in closed loop under different PWM methods. Chee Siong Tan et al. [11] Kumar.K et al. [12] and Shanmugasundaram R et al. [13] - [14] promoted the fuzzy logic controller for the BLDC motor control. Although many researchers have analyzed the BLDC motor performance using PI, PID and fuzzy logic controller, overtaking and speed drop during load change must be minimized [15] - [16]. In the PI controller integral action accumulates the error and causes a large overshoot. This is called winding up [17] - [18]. Juan W. Dixon et al. [19] proposed a method called less speed control sensor for BLDC motors. Therefore, the simple and effective controller is needed to control BLDC drive for electric vehicles [20] - [21]. In this article, the BELBIC controller is proposed to control BLDC drive and gives a comprehensive introduction and perspective of its applications in intelligent electric field drives [22]. BELBIC was introduced as a controller based on the limbic system calculation model of the mammalian brain. In recent years, this controller has been used for many industrial applications in control systems [23] - [24] and Drive [25-27]. This is a simple technique formed through mathematical equations [28] - [29].

II. BELBIC CONTROLLER

To improve speed performance controller with less processing time, easy and effective control BELBIC is proposed in this paper. It is proposed to reduce the overshoot, settling time and reduced speed during a load change. It can be done by offering BELBIC improved because of its dual feedback controller. PI and PI anti winding up are simple feedback controllers. BELBIC receives the speed error of the machine as a feedback and the controller output as another reaction. This results in a precise setting of the controller based on the status. BELBIC is based on the architecture of the "limbic system" of the human brain. The limbic brain is responsible for emotional learning of human beings. The block diagram of BELBIC controller is shown in Fig. 3.

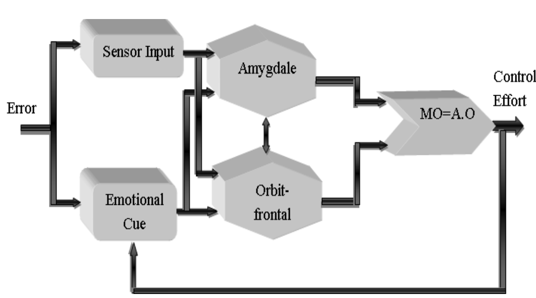

Fig 3: Block diagram of BELBIC controller.

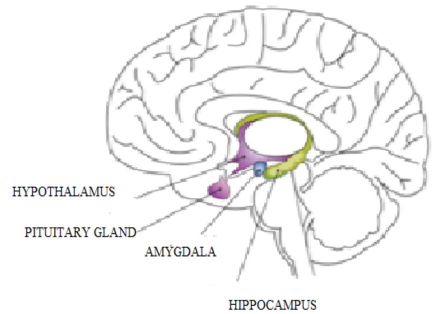

Fig 4: Limbic System of Brain [21]

Pre-processing of sensory input signals such as noise reduction or filtering can be done in the thalamus. Emotional Assessment stimulation signal is performed by the amygdala, a small role in the medial temporal lobe in the brain. Consequently, this emotional mechanism is used as a basis of states and emotional reactions. Initially, sensory input signals are in the thalamus for the pre-treatment on them. The limbic system of brain is shown in Fig. 4. In this article, the speed error is considered to sensory input. Sensory cortex and amygdala then receive their processed form and their outputs are calculated by amygdala and Orbitofrontal based on the received signal from the emotional environment. Final output is the subtraction of the amygdala and orbitofrontal cortex. One of the amygdala entries is named as connection and thalamic sensory input is calculated as maximum overall S that equation (15). This entry is not projected in the orbitofrontal part and cannot be inhibited which differ among other means amygdala.

$$A_{th} = i_{max} S_i \tag{15}$$

Every input is multiplied by a soft weight V_i in each node in Amygdala to give the output of the node. The O nodes' behaviors turn out their output signal by applying a weight W to the input signals as well as nodes. To adjust the V_i difference between the reinforcement signal rew and the activation of the A nodes is being made use. For tuning the learning rate the parameter is used and it is set to a constant value. As shown in equation (16) Amygdala learning rule is an example of simple associative learning system which is almost monotonic. For example, V_i can be increased.

$$\Delta_{vi} = \alpha\left(s_i \max\left(o, rew - \textstyle\sum A_j\right)\right) \tag{16}$$

Image is the learning step in the Amygdala. The reason of this adjusting limitation is that after training of emotional reaction, the result must be permanent, and it is handled through of the Orbitofrontal part when it is inappropriate [8]. Subtraction of reinforcing signal from the previous output E makes the signal of reinforcement for O nodes. To put it another way, comparison of the desired and actual reinforcement signals in nodes O inhibits the model output. The significant equation of the Orbitofrontal Cortex is drawn in Eq. (17).

$$\Delta w_i = \beta\left(s_i \sum\left(o_j - rew\right)\right) \qquad (17)$$

The amygdala and Orbit frontal learning rules are much alike, but the Orbitofrontal Weight W will be modified in both ways to extend and reduce as needed to track the proper inhibition.

The Linear Model of BEL Controller is mathematically represented by the following simplified Equations

$$A = G_A . SI \qquad (18)$$

$$O = G_{OC} . SI \qquad (19)$$

$$\frac{dG_A}{dT} = \alpha SI(ES - A) \qquad (20)$$

$$\frac{dG_{OC}}{dT} = \beta . SI(A - OC - ES) \qquad (21)$$

$$MO = A - OC \qquad (22)$$

Where MO is the Model Output, SI is the Sensory Input, ES is the Emotional Sensor, A is the Amygdala Output, O is the Orbitofrontal Cortex, αLearning rate of Amygdala, GA is the Gain for Amygdala and GOC is the Gain for Orbitofrontal Cortex. β is the learning rate of Orbitofrontal cortex

III. SIMULATION MODEL OF BLDC DRIVE

The complete model of the BLDC motor drive is simulated using MATLAB/ SIMULINK. It is shown in Fig. 5.

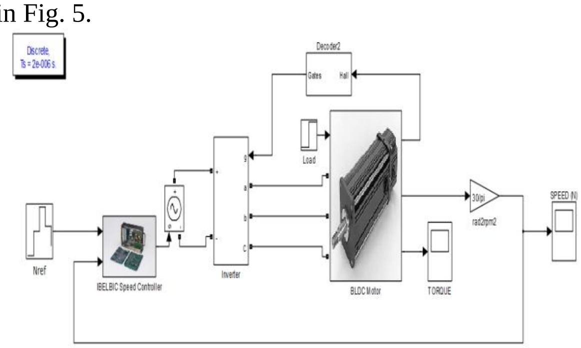

Fig 5: Simulation Model of BLDC Drive

In contrast to a brush DC motor, the switching of a BLDC motor is observed electronically. To rotate the BLDC motor, the stator windings must be activated in a sequence. It is important to know the rotor position to understand the sequence of winding will be energized. In the decoder unit, the rotor position θ is used for the back emf module [12] to generate the trapezoidal back EMF function. It is also used to generate the three outputs of the Hall Effect sensor. The outputs of the Hall sensor are multiplied with the output complement signal phase Hall sensor that results. It is compared to zero for generating trigger signals for an inverter. MOSFET based on a hexagonal bridge is developed as an inverter. The inverter module is activated by the trigger pulses generated by the decoder. DC current input to the inverter is controlled by the PI speed controller / BELBIC of [28-29]. The controller takes speed and compares them to the reference speed. BELBIC the action is performed to correct the speed error. Speed controller output BELBIC is controlled DC voltage to an inverter. MATLAB mathematical model model based BLDC motor is used in the simulation. It is powered from controlled inverter. The control circuit in closed loop produces a controlled rate with the minimum error.

IV. RESULTS AND DISCUSSION

The speed response of BLDC is analysed with BELBIC controller. The behaviours are observed under various operating conditions such as change in speed and load.

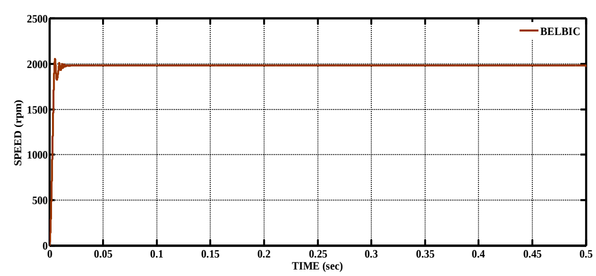

Fig .6: Speed response of PMBLDCM drive using BELBIC controller

Fig. 6 shows the Speed response of PMBLDCM drive using BELBIC controller. The motor settles at set speed quickly with overshoot. It runs at set speed till the load is varied. At the time of 0.5 Sec load is increased. The speed drops when the load is increased. It causes an increase in error sensed by BELBIC and it increases DC voltage to the inverter to increase the speed. The rise in voltage increases the speed and attains the set speed after restoration time.

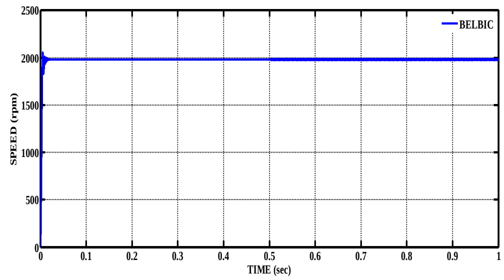

Fig 7: Speed response of PMBLDCM drive using BELBIC controller with 100% change in load

Fig. 7 shows the dynamic performance of the PMBLDCM drive system. Motor starts with no load and then load increased to 1.2 Nm. When load increases, speed is reduced, this increases speed error. BELBIC increases V* to increase speed to overcome the speed drop. It is observed that speed drop during load change and overshoot very less because of the emotional controller action.

When the load is increased the torque of the machine is increased with overshoot.

Table I. Performance of Belbic For Bldc Drive

Controller with reference speed of N= 1500 rpm	Type of controller	Peak overshoot %	Steady state error %	Speed drop during load %	Settling time after load Sec
	BELBIC	0.33	0.0125	8.33	0.06
Controller with reference speed of N= 2000rpm	Type of controller	Peak overshoot %	Steady state error %	Speed drop during load %	Settling time after load Change Sec
	BELBIC	0.8	0.00015	7	0.03
Controller with reference speed of N=2500 rpm	Type of controller	Peak overshoot %	Steady state error %	Speed drop during load %	Settling time after load Sec
	BELBIC	1.72	0.0125	6	0.02

This oscillation exists up to 0.145 sec at a speed of 1000 RPM. After load change, the motor settles with a restoration time of 0.015 sec.. Fig. 8 shows the Speed response of PMBLDC drive using BELBIC controller with a change in speed and load.

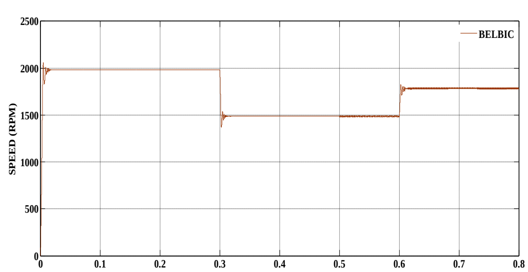

Fig 8: Speed response of PMBLDC drive using BELBIC controller with a change in speed and load

The motor rapidly settles at the set speed with less overshoot compared to anti windup PI controller. It runs at the set speed till the load is varied. At the time of 0.5 Sec, the load is increased. The speed drops when the load is increased. It causes an increase in error sensed by BELBIC controller and it increases DC voltage to the inverter to increase the speed. The perfect rise in voltage increases the speed and attains the set speed after the restoration time. The speed drop and restoration time are less compared to the above said controllers. Fig. 9 shows the Torque Response of BLDC Motor Drive using BELBIC controller with change in Load.

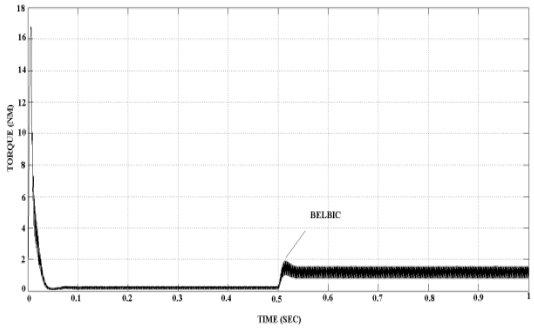

Fig 9: Torque Response of BLDC Motor Drive using BELBIC controller with change in Load

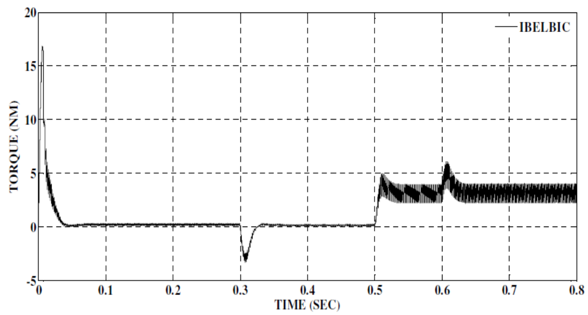

Fig 10: Torque Response of PMBLDCM motor drive using an BELBIC with change in load

From the Fig. 10, the controllers have nearly equal high starting torque and reaches zero when the motor attains the set speed. When the load is increased, torque of the machine is increased with little overshoot. This oscillation is less in BELBIC than in the other controllers. The controller performance for speed 1500 RPM,2000 RPM,2500 RPM using BELBIC is tabulated in Table 1.

V. CONCLUSION

The crucial characteristics motor in an electric vehicle is the precise speed and stability to changes in load. In this article, BELBIC are used as speed monitors in the control of BLDC motor and simulated in Matlab / Simu-link. From the simulation results, the system performance is improved by BELBIC in terms of overshoot, steady state error, the falling speed when load change and the settling time after load change. The BELBIC controller is better in terms of stability. It can be quickly in speed after the change of load than the other two controllers. Simulation results show that learning using imitative, BELBIC could quickly learn to produce appropriate control signals to control a system point of unstable equilibrium. Meanwhile BELBIC controller produces the same response to the rated speed, the rated speed above and below the rated speed of the machine. Thus BELBIC controller BLDC motor drive is suitable for electric vehicles to operate in a wide speed range and frequent load change.

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