IJCRT.ORG ISSN : 2320-2882
INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

PID CONTROLLER BASED SPEED CONTROL OF BLDC MOTOR WITH REGENERATIVE BRAKING

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Abstract: BLDC motor is broadly utilized in several industries like for making electrical vehicles. Low ripple input supply and an appropriate speed controller are required to achieve the desired motor performance. PID controllers can be utilised for speed control due to its benefits of rapid response time and error removal. Regenerative braking system is the best solution for utilising wasted energy which is generated while applying brake in electrical vehicle. In this paper speed control strategy with regenerative braking system is proposed with the help of PID controller and boost converter which is simple to implement .It is capable to be operated in lower speed due to adding boost converter for regenerative braking system. To verify the analysis, simulations works were done. They show the effectiveness of the proposed control strategy.

***Index Terms* - BLDC motor, PID controller, boost converter ,MATLAB.**

1.INTRODUCTION

Now a days fossil fuel is limited and it is going to end early. Electric vehicle is the best solution to overcome that problem. Electric vehicles can provide some special features such as low greenhouse emissions, high efficiency, silence operation, fine control over conventional vehicles etc.

In electrical vehicles different types of motors are used like permanent magnet synchronous motors, switching reluctance motors, brushless DC motors, AC induction motors, DC series motors. Mostly for light weight applications BLDC motor is used like 2 wheelers and 3 wheelers electric vehicles. BLDC motors are also used in various industrial applications because of its good weight/size to power ratio. It is easy to control speed of BLDC motors.

Regenerative braking is used to recover the energy during deceleration process. This process can save 8-25% of total energy used by vehicle. This system can be used in hybrid electric vehicles and pure electric vehicles. By using regenerative braking system the effective performance of battery is increases with prolonged distance. Regenerative braking system can utilize the wasted heat energy further by converting energy into electrical energy and then generated electrical energy can further be used by storing the charges in battery and again give supply to the motor. This thesis designs a speed controller of BLDC motor with the help of PID controller and regenerative braking system with the help of boost converter.

2. MATERIAL

2.1 BLDC motor

The most common and ideal motors for electric vehicles (EVs) are brushless DC motors (BLDC), which have great speed torque characteristics, a wider speed range, higher power densities[7]. Electronic commutation is necessary for the motor to operate instead of brushes. BLDC motors are lighter in weight as compared to other motors with same output power rating. As no brushes are used hence no wear and tears and BLDC motor can run for longer period without sparking. BLDC motor has longer life. The BLDC motor is highly efficient and requires low maintance. BLDC motor are used in applications like pumping water, making hybrid vehicles and electric vehicles, robotics, automotive electronics etc. for various applications.

Hall sensors are used in BLDC motor to identify correct position of motor. By knowing the rotor position the phase current can be turned on in sequence accordingly. Hall sensors measure the magnetic field which is produced by permanent magnet on the rotor and rotor changes its position accordingly from north to south position also output of the hall sensors change.

For calculating PID values there is need of transfer function. Basic transfer function of BLDC motor is calculated by using below formulas.

a) $G(s) = \frac{1/Ke}{Tm.Te.s^2 + Tm.s + 1}$ (1)

b) $Te = \frac{L}{3R}$ (2)

c) $Tm = \frac{3RJ}{Ke.Kt}$ (3)

Where
Tm=Mechanical time constant
Te=Electrical time constant
Ke=Emf constant
Kt= torque constant

After calculating all values transfer function is

$G(s) = \frac{6.211}{0.0002157.s^2 + 0.0327.s + 1}$ (4)

2.2 PID controller

A PID controller is a device that regulates variables such as temperature, flow, pressure, and speed. Due to its benefits, PID controllers are used in industries in about 95% of closed loop automation sector. PID controller improves stability of the system and reduces steady state error of the system. It is easy to implement and feasible as compared to other controller. It makes system faster by reducing the time constant. PID gain paramters such as Kp,Ki and Kd affects on system's overall performances. Different tuning techniques, including the manual tuning method, the Ziegler-Nicholas tuning method, and the Cohen-coon tuning method, are used to select the PID gain values.

Ziegler Nicolas method is one of the method to identify PID gain values. As shown in fig1 by measuring step response parameters value such as L and T from step response curve PID gain values are measured by formulae given in table 1.

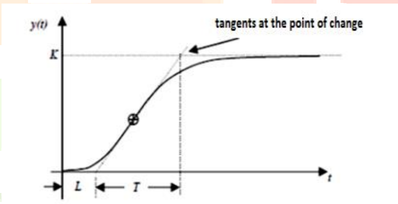

Fig 1 PID Ziegler-Nichols tuning curve

	PID Type	K_P	$T_I = \frac{K_P}{K_I}$	$T_D = \frac{K_D}{K_P}$
1.	P	$\frac{T}{L}$	∞	0
2.	PI	$0.9\times\frac{T}{L}$	$\frac{L}{0.3}$	0
3.	PID	$1.2\times\frac{T}{L}$	$2\times L$	$0.5\times L$

Table 1 Ziegler Nichols PID parameters

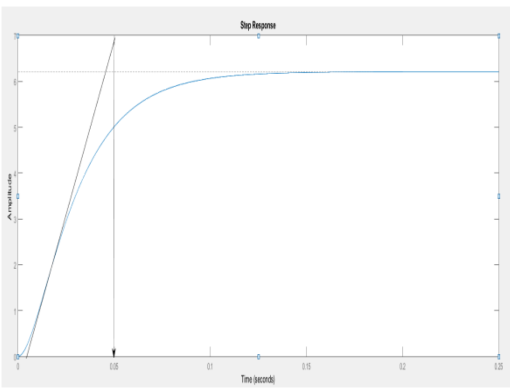

Fig 2 Step response curve

L and T value is measured from above step response curve shown in fig 2 such as there values are L=0.008 and T=0.05 and from these values PID parameters value are obtained as Kp=7.5,Ki=468.75,Kd=0.03.

2.3 BOOST CONVERTER:

Boost converter is a DC to DC converter. It is used to increase the level of output voltage. It is simple circuit which consists of an inductor, a semiconductor switch, a diode and a capacitor. It is easy to analyze and understand. Below are formulas for calculating the boost converter's parameters.

- $D= 1 - \frac{Vs}{Vo}$ (5)
- $L== \frac{D(1-D)(1-D)*R}{2F}$ (6)
- $C= \frac{D*2*F}{R}$ (7)

Below Table 3 shows the calculated parameters of boost converter by using above formulae.

Parameters	Specifications
Source voltage(Vs)	12v
Load voltage (Vo)	48v
Switching Frequency	1KHz
Inductor(L)	2.34mH
Capacitor(C)	3.75µF
Resistance(R)	100Ω

Table 3 Boost converter parameters

3.SIMULATION AND RESULT

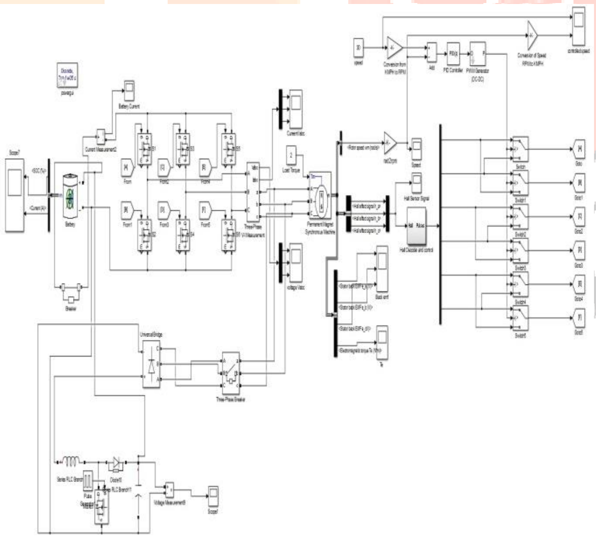

Fig 3 Matlab simulation of regenerative braking

Above fig 3 shows the simulation of proposed work. Here 48 v battery is used with SOC% as 80% and boost converter is connected to motor 3 phases through 3 phase circuit breaker and universal bridge. Universal bridge is used to convert ac into dc. Initially 3 phase circuit breaker and single phase circuit breaker are opened. For braking system circuit breaker has given timing as 0.5 to 1 sec at that time single phase breaker which is connected to 3 phase inverter circuit will open and disconnect supply to motor but motor will continue to run due to moment of inertia at that time back emf is generated .3 Phase circuit will close during braking time and connect motor to boost converter. Boost converter output is already connected to battery to store generated back emf . In this way regenerative braking system is utilized to convert kinetic energy into electric energy.

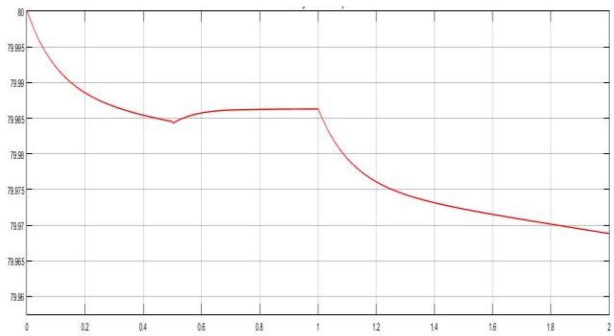

Fig 4 % SOC of battery

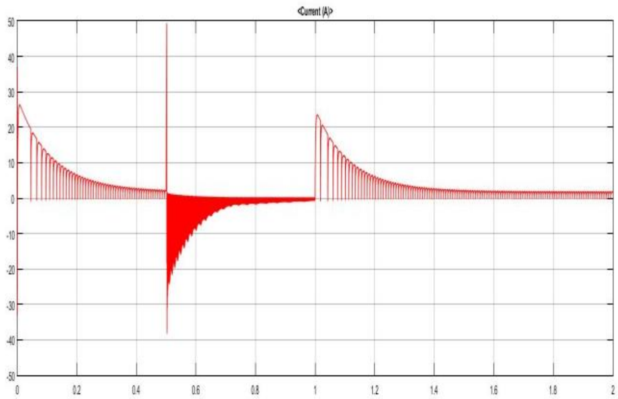

Fig 5 Battery current

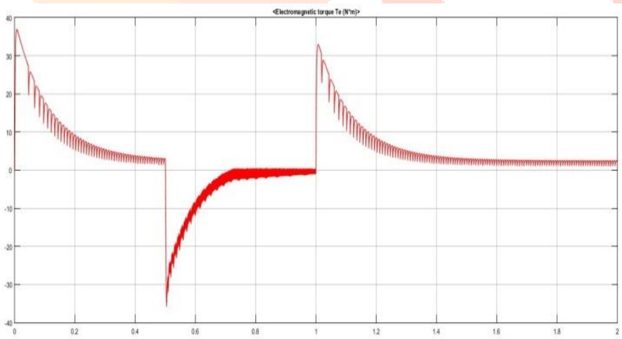

Fig 6 Torque

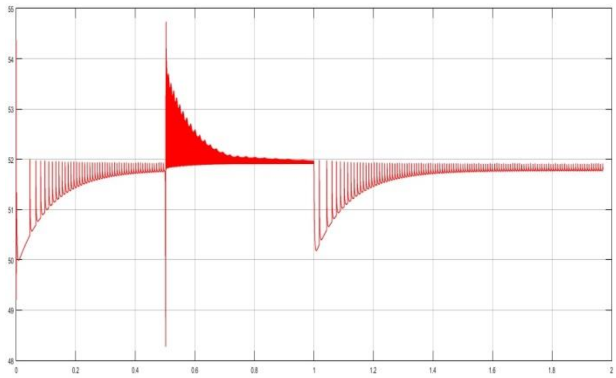

Fig 7. Generated voltage

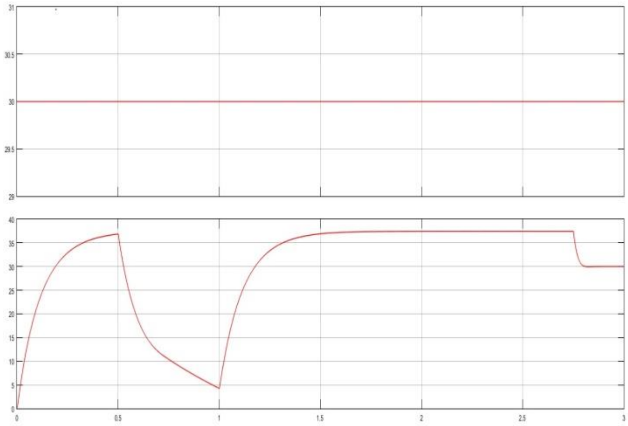

Fig 8 Controlled Speed of motor

Fig 4.shows the %SOC of battery having 80% initially and it decreases as battery utilization but brake applied in between 0.5 to 1 sec at that time %SOC increases from 79.9835 to 79.9850 % and then decreases when brake is not applied. In fig5 shows battery current when battery is utilized then its value is positive but when brake is applied then it goes to negative which indicate that battery is charging. Similarly motor torque goes to negative when is applied as at that time motor supply is disconnected and motor is running due to moment of inertia hence torque graph shows negative value. Fig 7 shows graph of generated voltage as when is not applied voltage value is 52v and when brake applied its value spike to 54v.In fig 8 shows graph of speed of motor where 30km/hr reference speed is given to PID controller and below graph shows controlled speed of BLDC motor.

4. CONCLUSION

A three phase BLDC motor speed controller has been designed based on PID controller with regenerative braking system with the help of boost converter. From fig 7 it is observed that in regenerative braking system generated voltage is 2 volts when brake is applied in between 0.5 to 1 sec. SOC of battery is increased to 0.0015% when brake is applied as shown in fig 4 which gives indication of battery charging. Fig 6 shows torque graph such as negative while braking it means motor run due to moment if inertia .Current graph is negative when brake is applied which shows that battery is charging while braking. Fig 8 shows the graph of reference speed graph and actual controlled speed graph.

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