

Modelling and Simulation of THC for BLDC Motor Drive

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Abstract — Modelling and simulation of a torque hysteresis controller for brushless DC motors. Brushless DC (BLDC) motors can offer great advantageous compared to other machines used in industrial applications due to its compactness, high torque density, simpler controller and lower maintenance. At first the mathematical modelling of BLDC motor that is suitable to analyse the dynamic performance will be given. A method of torque hysteresis controller will be adapted to drive the motor such that the current (or torque) ripple can be restricted within the predefined band-gap. Moreover, a new current blocking strategy is proposed to prevent the current drained from DC supply when the torque demand is set to zero, that can prolong the capacity voltage of batteries. Some simulation results were carried out using MATLAB/ Simulink to verify the proper modelling as well as functionality of the controller.

Keywords-component; Brushless DC motor; Hall effect; Simulation, Torque hysteresis controller.

I. INTRODUCTION

Several years ago, brushes DC motors were regularly used in many applications since it has a simple construction, easy to control and can give superior dynamic performance. However, this type of the motor that equipped with commutator and brush requires frequently maintenance, cannot be performed at dirty or explosive environment and at very high speed operations. Due to these reasons, many types of motors were developed to minimize or solve the problems such as induction motor, switched reluctance motor and permanent magnet synchronous motor. Among these types of motors, the use of permanent magnet synchronous machine (PMSM) has recently received much attention, particularly for electric vehicle applications. This mainly due to the fact that the PMSM offers higher efficiency and torque density (i.e. Nm/kg). In general, the PMSM can be classified into two types depending on back-emf wave shape production, i.e. sinusoidal and trapezoidal wave shapes. The one that is operated in sinusoidal is normally referred to as permanent magnet AC motor or brushless AC motor. The latter one that produces trapezoidal back-emf wave shape is normally called as brushless DC motor (BLDC). It

can be shown that the production of torque in BLDC is quite similar to that of brushes DC motor with simple control algorithm and comparable performance. In many electrical drive applications, it is desirable to achieve fast torque dynamic response as produced in brushes DC motor, whereby the torque can be directly controlled by regulating the armature current. Several papers were reported to achieve this requirement, for examples ; fully utilized the available DC link voltage through over modulation strategy and generated the maximum possible voltage vector that is tangential to the flux component to have a quick change of torque dynamic. Ultimately, all these methods used a vector control which is complicated to be implemented. This paper will discuss the principle of torque hysteresis controller for BLDC motor to provide naturally current protection, reliable and fast torque dynamic control. In fact the hysteresis controller is known to provide high control bandwidth and robust control. It will also present a new current blocking strategy once a torque pedal of electric vehicle is released (i.e. $T_{ref} = 0$) so that , it can preserve the capacity of voltage of batteries.

II. METHODOLOGY

There are different way to control speed of BLDC motor such as by with current controller and without current controller and torque controller ,but by using torque controller its is very easy to control speed of BLDC motor by PI controller, where by using hall effect sensors ,the sensor which can sense the phase shift of electromagnetic pole of BLDC motor. This method is very convenient and easy to work .

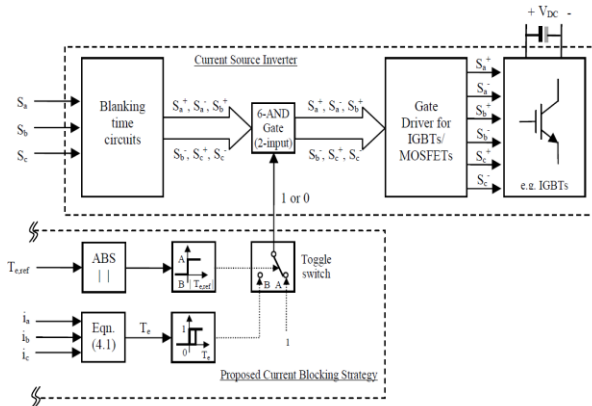


Figure 1. Block Diagram of Proposed System

This section will present that the ripples were present in the torque whenever the speed of motor increases and decreases. In the THC method, the ripple should be minimized by current regulation within the hysteresis band around zero Amperes (A). By using a two-level inverter where MOSFETs play a switching role, a two-level inverter provides the supply AC voltage to the BLDC motor. Whenever the speed changes, ripples increase, but by using THD, here we can control the ripples up to a particular band which we provided.

III. PRINCIPLE OF TORQUE HYSTERESIS CONTROLLER

It is desirable to provide current limitation and fast torque dynamic control for many electric drive applications. A simple method that can offer these requirements is the use of a torque hysteresis controller (THC) technique. Figure 2 shows the structure of the torque hysteresis controller for a BLDC motor. The control of torque can be established by controlling the three-phase current at its reference. As shown in Fig. 3, the motor currents need to be controlled satisfying their references (i_a^* , i_b^* and i_c^*). The generation of reference currents is based on the torque demand (i.e. $I_{ref} = T_{e,ref} \times G1$) and decoded signals (H_A' , H_B' and H_C') which are derived from the Hall Effect signals (H_A , H_B and H_C) as given in Table 1.

Table 1. Derivation of Decoded signals effects on hall effect sensor

Each phase current is controlled using a 2-level hysteresis comparator, which is responsible for producing appropriate switching status to be fed into the inverter, either to increase or

decrease the phase current such that its current ripple is restricted within the hysteresis band (HB). In such a way, the

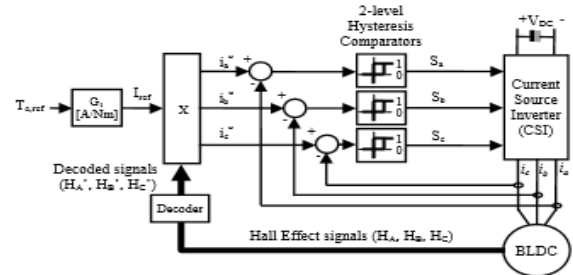


Figure 2. Structure of Torque Hysteresis Controller (THC) drive for brushless DC (BLDC) motor

reference current for each phase will have the same pattern waveform with the respective decoded signals.

III. PROPOSED CURRENT BLOCKING STRATEGY

This section will present a new current blocking strategy to avoid waste of energy from the battery (due to the current drawn) when the torque pedal is released (i.e. $T_{e,ref} = 0$) for electric vehicle applications. In the conventional THC method, the current is still drawn from the battery even when the reference current is set to zero; as the phase current needs to be regulated within the hysteresis band around zero Amperes (A). To block the current drawn from the battery, the proposed current blocking strategy will turn OFF all IGBTs/MOSFETs in the inverter when the torque pedal is released ($T_{e,ref} = 0$) and once the actual motor torque is completely reduced to zero. This can be simply established with minor modification on the original structure of THC using a hysteresis comparator as shown in Fig. 3.

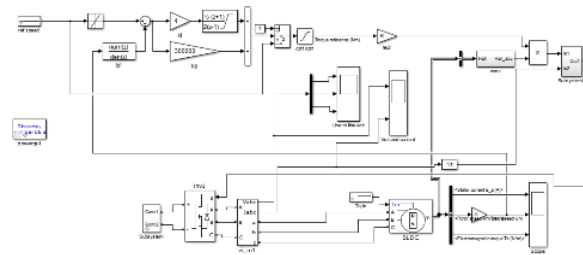


Figure 3. Modelling of BLDC motor without Torque hysteresis controller

IV. MODELLING OF TORUE HYSTERISIS CONTROLLER BY USING SIMULINK

Table .Rating Of BLDC motor

Parameter	Value
Rated Voltage	24 v
Resistance of the stator (R)	0.2 ohm
Inductance of the stator (L)	8.5 mH
Moment of Inertia (J)	0.0083
Load Torque (TL)	4N-m
No of Pole Pairs	4

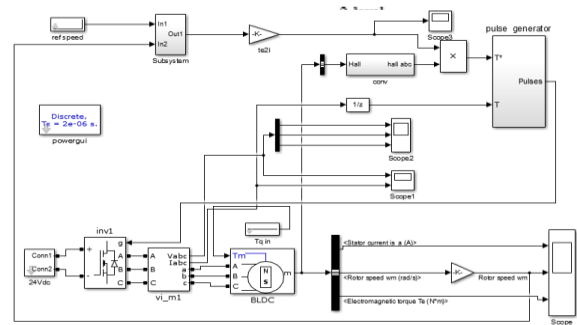


Figure 5. Modelling of BLDC motor without Torque hysteresis controller

$$\% \text{ Ripple} = \frac{\text{Actual torque} - \text{Measured Torque}}{\text{Actual Torque}}$$

$$= \frac{1.5 - 1.21}{1.5}$$

$$= 19.33\%$$

%Ripples in without THD =19.33%

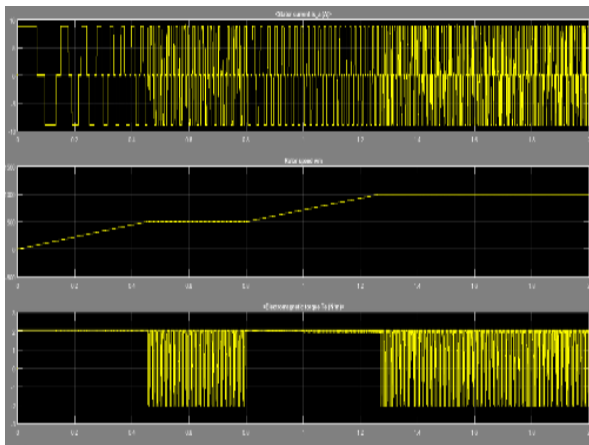


Figure 4. Simulink results with Torque Hysteresis Controller Ripples without Torque Hysteresis Controller

Consider, $T = 1.5 \text{ Nm}$

Rate 0.9, 2, 2, 2, -0.1, .05

Average =

$$\frac{0.9 + 2 + 2 + 2 - 0.1 + 0.5}{6} = 1.21$$

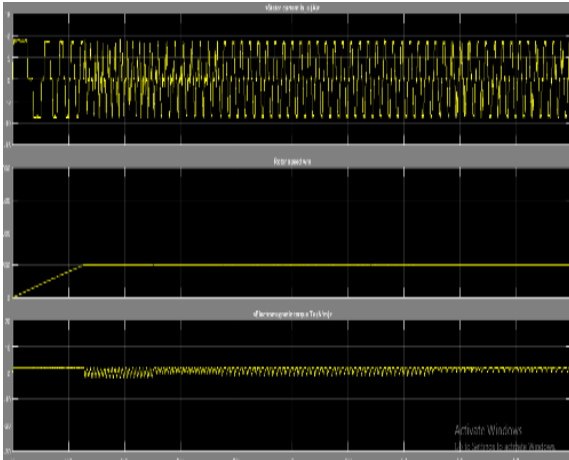


Figure 6. Simulink results with Torque Hysteresis Controller Ripples without Torque Hysteresis Controller

Consider, $T=1.5 \text{ Nm}$

Rate 1.5, 1.8, 2, -0.5, 1.8, 1.9

Average =

$$\frac{1.5 + 1.8 + 2 - 0.5 + 1.8 + 1.9}{6} = 1.33$$

% Ripple = $\frac{\text{Actual torque} - \text{Measured Torque}}{\text{Actual Torque}}$

$$= \frac{1.5 - 1.33}{1.5}$$

$$= 11.33\%$$

% Ripples in without THD = 11.33%

V. CONCLUSION

This paper has presented the modelling and simulation of torque hysteresis controller for BLDC motor in which comparison between with and without torque hysteresis controller work done. The ripple can minimize by using torque hysteresis controller at any load condition. Here we can see difference of torque at both the condition with and without THC. Percentage ripples in with THD is high as compare to with THC. By using the THC, The speed of BLDC motor can be stay constant at any load condition. Moreover, a new current blocking strategy to prevent the energy wastage

from the batteries such that it can prolong the capacity of voltage battery is proposed. From the simulation results obtained, it showed that the hysteresis controller can offer inherent current protection/limitation and robustness in controlling the motor torque.

VI. REFERENCES

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