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Performance Of BLDC Motor Using SIMULINK For Torque And Speed Analysis

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ABSTRACT- BLDC Motors have been gaining enormous applications & increasing popularity because of higher efficiency & speed in comparison to the conventional DC Motors. These motors find higher rating applications in aircraft; satellite systems as well as in traction systems. Since an “electronic controller” is the most efficient part of these BLDC Motors as they can’t operate without them, thereby, in this paper the modeling of Brushless DC Motor drive system along with the speed & torque control is accomplished with the usage of semiconductor switching devices such as MOSFET & JFET and their corresponding results have been compared & analyzed. Test results are performed via MATLAB/SIMULINK and the results thus, obtained show that the model performances are satisfactory.

Keywords: BLDC Motor, Back EMF, PI Controller, Torque Angle, Stator Current.

INTRODUCTION:

BrushlessDC Motors (**BLDC motors**) are synchronous motors that are powered by a DC electric source via an integrated switching power supply, which produces an AC electric signal to drive the motor &semiconductor devices such as MOSFET control the inverter output amplitude and waveform and frequency (i.e. rotor speed). The motor part of a brushless motor is generally a permanent magnet synchronous motor, but can also be a switched reluctance motor, or an induction motor. These motors cannot operate without its electronic controller & therefore, a brushless DC Motor is a combined machine system that joins into a single unit an ac motor, solid state semiconductor switching devices and a rotor position sensor. The solid state semiconductor switching devices employ transistors for low-power driving arrangements and thyristors for high-power systems. This paper deals with the simulation model of a BLDC Motor and results are examined for the speed & torque control of these machines. Also, the comparison has been done by varying the GATE signal magnitude & nature through different switching devices such as MOSFET & JFET.

(a)Description of a BLDC Motor:

A BLDC motor is viewed as inside out DC motor because its construction is opposite to that of a conventional dc motor. It has permanent magnet field poles on the rotor and polyphase armature winding on the stator. PMDC motors are smaller in size than the corresponding rated field wound type motors, this fact partially offsets the high cost of permanent magnets. Obviously, these offer shunt

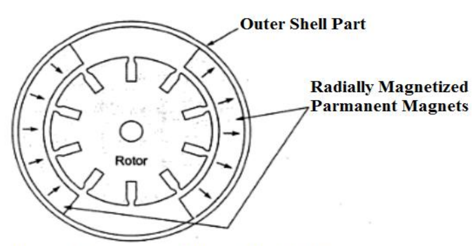
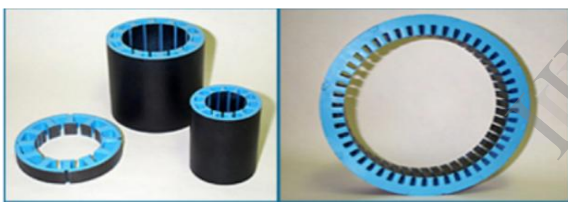


Figure (a.1)- Sectional View of BLDC Motor

type characteristics and can only be armature controlled. The risk of permanent magnetism getting destroyed by armature reaction has been greatly reduced by the new PM materials.

BLDC Motors have many similarities to AC Induction motors and brushed DC Motors in terms of construction and working principles respectively. The BLDC motor stator is made out of laminated steel stacked up to carry the windings. Windings in a stator can be arranged in two patterns; i.e. a star pattern (Y) or delta pattern (Δ). The major difference between the two patterns is that the Y pattern gives high torque at low RPM and the delta pattern gives low torque at low RPM. This is because in the delta configuration, half of the voltage is applied across the winding that is not driven, thus increasing losses and, in turn, efficiency and torque.



(Figure a.2- Steel Stampings in Stator of a BLDC Motor)

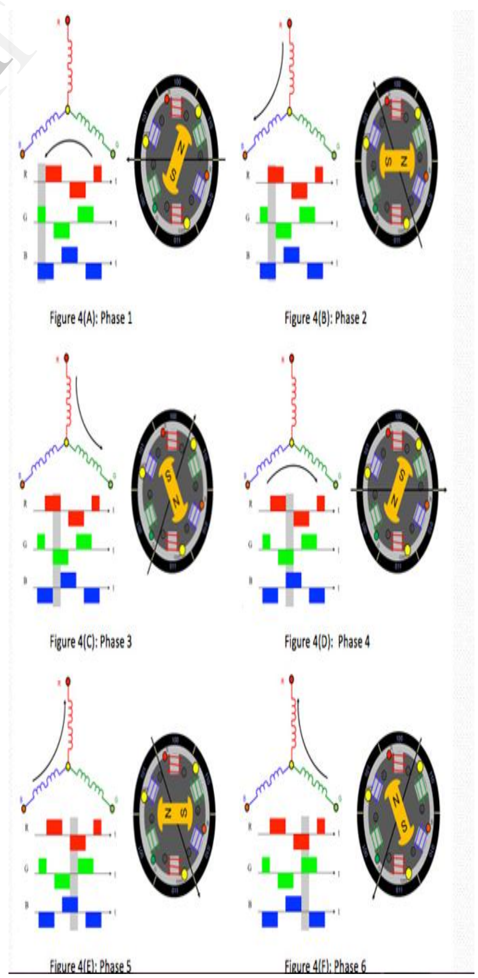
(b)Working of a BLDC Motor:

Switching Devices- In any power conversion process small power loss and high efficiency are important because of two reasons that is the cost of the wasted energy and the difficulty in removing the heat generated due to the dissipated energy. Other important considerations are reduction in size, weight and cost.

Operation: The underlying principles for the working of a BLDC Motor are same as for a brushed DC Motor i.e. Internal Shaft Position feedback. In case of a Brushed DC Motor, feedback is implemented using a mechanical commutator and brushes whereas it is achieved in a BLDC Motor via multiple feedback sensors. The most commonly used sensors are Hall Sensors and Encoders.

Note: Hall Sensors work on the hall-effect principle that when a current carrying conductor is exposed to the magnetic field, charge carriers experience a force based on the voltage developed across the two sides of the conductor.

The working could clearly be understood with the help of following schematic diagram:



(Figure- b.1- Schematic Working of BLDC Motor)

Controller- There are various type of controllers which are used for the gating of switching devices such as:

1. PI
2. PD
3. PID
4. Fuzzy
5. Neural Network

We are using the PI controller for the gating of switching device. The definition of a proportional feedback control is

$$u = K_{p}e \qquad (1)$$

where e = is the "error"

K_P = Proportional gain

The definition of the integral feedback is

$$u = K_{I}\int e \, d\tau \qquad (2)$$

Where KI is the integration gain factor.

In the PI controller we have a combination of P and I control, i.e.:

$$u = K_{p}e + K_{I}\int e \, d\tau \qquad (3)$$

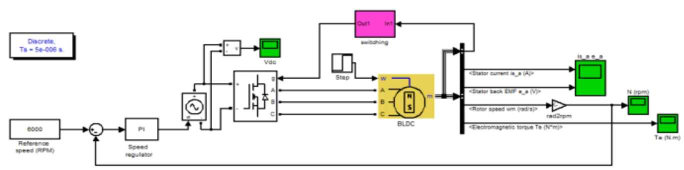
$$u = K_{p}e + \frac{1}{\tau_{I}}\int e \, d\tau \qquad (4)$$

$$u = K_{p}\left(e + \frac{1}{\tau_{N}}\int e \, d\tau\right) \qquad (5)$$

Where τ_I = "Integration time" [s]
τ_N = "Reset time" [s]

Modeling of a BLDC Motor:

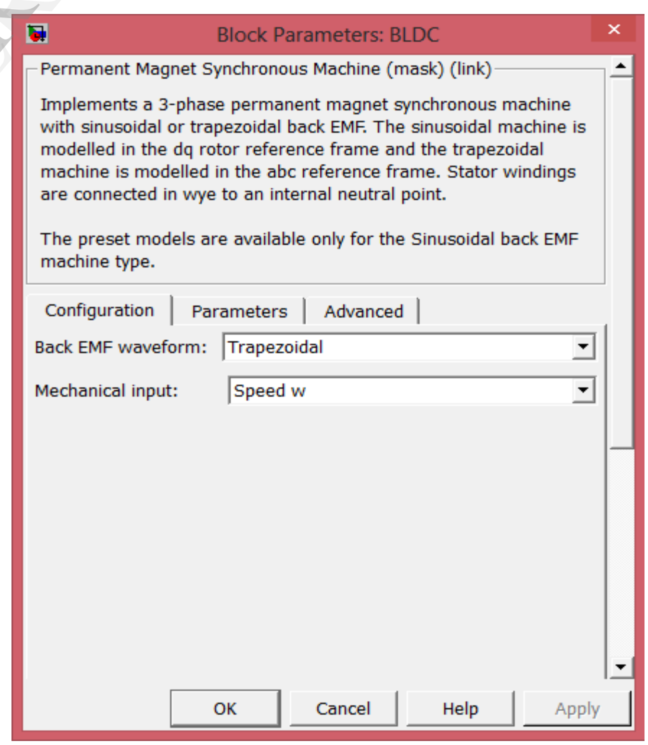
For the speed control of a BLDC Motor, we have used the following scheme:



(Figure c- Working Model)

We have designed the switching block for the Gating of MOSFET.

In the motor block, following parameters have been entered as:

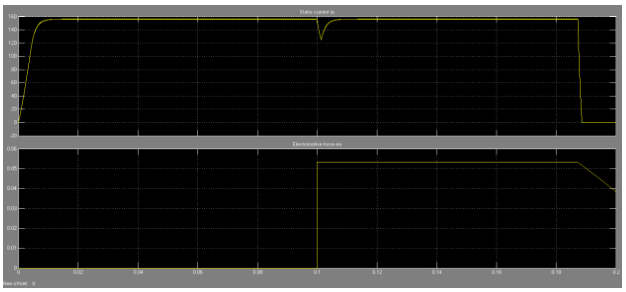


(Figure d- Parameter Block)

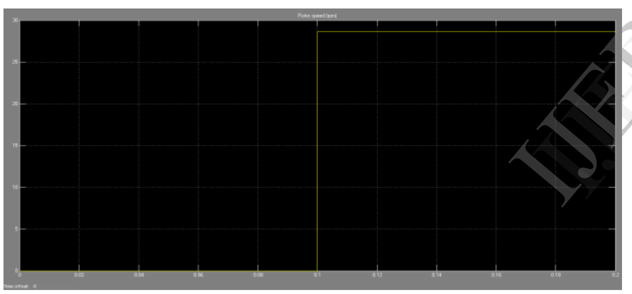
Results:

The inputs of the converter block is speed, rotor position, back emfs and voltage, the output of the block is current. We have seen that the stator current becomes constant after sometime with reduced spikes and therefore, performance of BLDC motor has improved a lot.

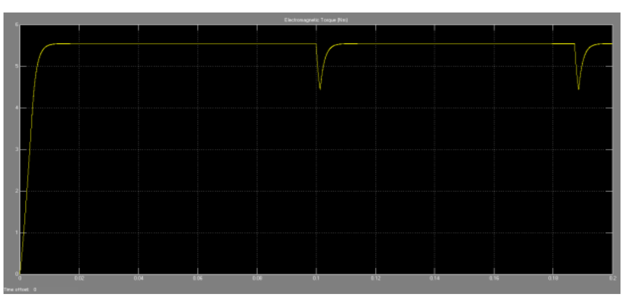
Stator Current & Back EMF:



Rotor Speed:



Electromagnetic Torque:



(Figure D- Output Waveforms)

Conclusions:

Permanent-magnet brushless dc motors is moreaccepted used in high-performance applications because oftheir higher efficiency, higher torque in low-speed range,high power density, low maintenance and less noise thanother motors. In this paper BLDC motor mathematicalmodel is developed. Finally closed loop speed controlBLDC is carried out and simulation results are presented.

The performance evaluation results show that thismodeling is very useful in studying the high performancedrive before taking up the dedicated controller designconcept for evaluation of dynamic performance of themotor. Simulation results are shown for various loadingconditions.

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