Performance Analysis of Brushless DC (BLDC) Motor without Controller using MATLAB/SIMULINK Environment

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Abstract— The simulink/MATLAB model is designed for analyse the performance of Brushless DC motor. In model there were no controller used for speed control or position control. Brushless DC motors is most popular and widely used motor in applications like aerospace, automotive, appliances, medical, automated industrial equipment as well as instruments. BLDC motors used due to its characteristics like high efficiency, high power density, fast dynamic response, high reliability, less maintenance requirement, low weight and cost. Also BLDC motor used for noiseless operation and available in higher speed ranges. The simulink model given can work for any rating of BLDC motor data. This paper presents the model construction of a brushless DC motor via MATLAB/SIMULINK without any controller.

Key words: MOSFET, Inverter Bridge Circuit, BLDC Motor

I. INTRODUCTION

Brushless DC motors is one type of permanent magnet synchronous motor (PMSM). Permanent magnet synchronous can be classified in two type based on the induced EMF wave shape, i.e. Trapezoidal wave and sinusoidal wave. The sinusoidal wave shape motor is known as permanent magnet synchronous motor and the trapezoidal wave shape type motor is known as brushless dc (BLDC) motor or permanent magnet (PM) brushless dc motor. Permanent Magnet Brushed DC and PMBLDC motors are the combination of permanent magnet and electromagnetic fields to generate torque or force resulting in motion. In DC motor current is switched automatically to different windings by means of brushed and commutator to generate continues motion. As name suggests Brushless DC motor do not have brushes for commutation. BLDC motor is electronically commutated motor. Instead of Brushes and commutator it use drive amplifier consists semiconductor switches for commutation.

II. STRUCTURE OF BRUSHLESS DC MOTOR

Based on construction and working principle BLDC motor is similar to the AC induction motor and brushed DC motor. BLDC motor classified in three types: single-phase, two-phase and three-phase configuration. Out of these three, a three-phase BLDC motor is most famous and widely used.

A. Stator

The BLDC motor stator consists of laminated steel stacked up to carry the windings. Stator windings can be arrange in two manners; i.e. a star(Y) pattern gives high torque at low RPM and delta(Δ) patterns gives low torque at low RPM. Reasons for that are in delta configuration, half of the voltage is applied across the windings which are not driven so in turn, efficiency and Torque it increase the losses. Due to that reason most BLDC motors have stator windings connected in star pattern. Selection of laminated steel and windings for construction of stator must be proper for better motor performance. Improper selection may increase many problems during production like market delays and increased design costs.

B. Rotor

A rotor of BLDC motor consists of permanent magnets and can vary from two to eight pole pairs depending on the application requirement. Based on requirement of magnetic field density rotor material can be selected. Ferrite magnets are most traditionally used material to make rotor due to its less cost but its provide low flix density, though alloy magnet is more preferred when high flux density require.

C. Hall Sensors

BLDC motor is electronically commutated so to rotate BLDC stator windings of motor must be energized in the appropriate sequence. To energise the proper sequence it is necessary to identify the rotor position. The hall sensors are used to sensed the rotor position. Most of the BLDC motor consist of three hall sensors which are embedded onto the stator at non-driving end. whenever Rotor magnetic poles N or S pole are passes nearer to the hall sensors, they generate the HIGH or LOW level signal which is used to find the position of rotor. By combinations of three hall sensor signals, exact commutation sequence can be determined to turn on/off the proper pair of switches. In operation of three phase BLDC motor at a time two electrical windings are energized.

III. WORKING PRINCIPLE AND OPERATION

The working principle of BLDC motor are as same as like for brushed DC motor but there is little difference in commutation process. In case of Brushed DC motor feedback is implemented by use of mechanical parts like brushes and commutator while In case of Brussless DC motor feedback is achieved by hall sensors. A three phase Brussless DC motor mainly consists of star (Y) connected type stator, permanent magnet type rotor as well as for detection of position of rotor it consists of hall sensors. On the basis of rotor position sensed, there are two types of outputs: a 60˚ and 120˚ phase shift. after 60˚ rotation of rotor one of the three hall sensors changes its state which used to updates the phase current switching by every 60˚.

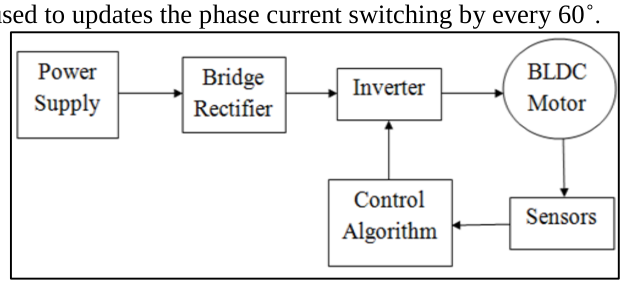

Fig. 1: Basic Block diagram of BLDC motor

Figure 1 shows the basic block diagram of BLDC motor with feedback control. The motor is fed by power supply through bridge rectifier and three phase inverter circuit. The outputs of BLDC motor hall sensors are used to gating signals for the inverter. The speed control is achieved by modulating these commutation gate pulses to another desired high frequency pulses. The DC voltage from bridge rectifier block is applied to BLDC motor through inverter. Three leg inverter converts these DC voltage into three phase AC. Simulation model of BLDC motor consists of BLDC motor, six MOSFET's, AND gates etc.

IV. SIMULATION AND RESULT

The overall simulation model of BLDC motor drive mainly consists of three components i.e. the Inverter block, BLDC Motor block and Gate pulse block. Brushless dc motor is driven by a 3 phase inverter which is called, six-step commutation. The inverter block in simulation model consists of six MOSFET switches. A signals from hall is changes every after 60˚, so for completion of electrical cycle six steps are necessary. Each interval starts with the rotor and stator field lines 120˚ apart and ends when they are 60˚ apart. When field lines are perpendicular maximum torque is reached. The phase commutation sequence is AB-AC-BC-BA-CA-CB and each conducting stage is called one step. So at a time only two phases are conduct and third phase is floating. To produce maximum torque, the inverter should be commutated after every 60˚ so that current is in phase with the back EMF.

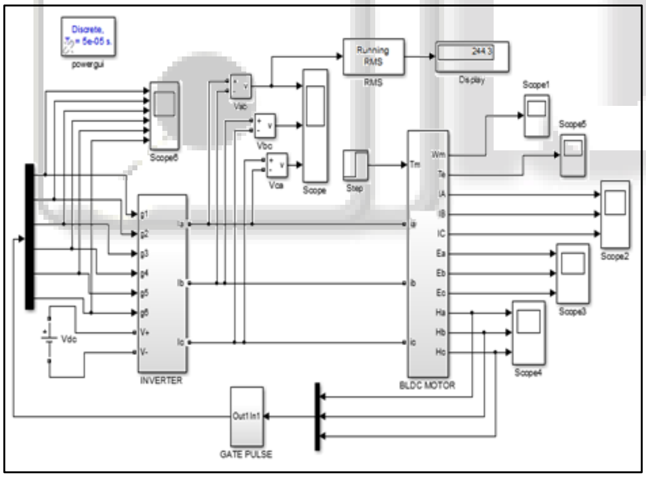

Fig. 2: Brushless DC motor Matlab Simlation

Table 1 shows the switching sequence for clockwise mode (60˚).

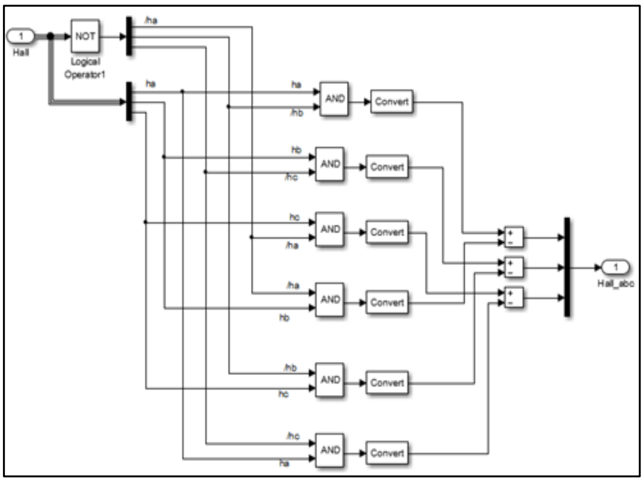

Fig. 3: Gate pulse logic operator

Hall Sensor Input			Active Switch		Phase Current		
H1	H2	H3			A	B	C
0	0	1	S5	S4	OFF	-	+
1	0	1	S1	S4	+	-	OFF
1	0	0	S1	S6	+	OFF	-
1	1	0	S3	S6	OFF	+	-
0	1	0	S3	S2	-	+	OFF
0	1	1	S5	S2	-	OFF	+

Table 1: Switching Seqence for Clockwise Mode

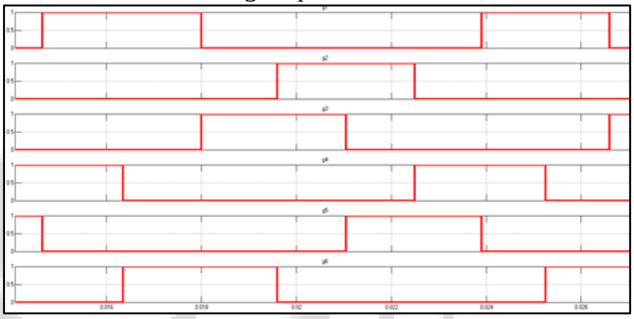

Fig. 4: Gate pulse generation

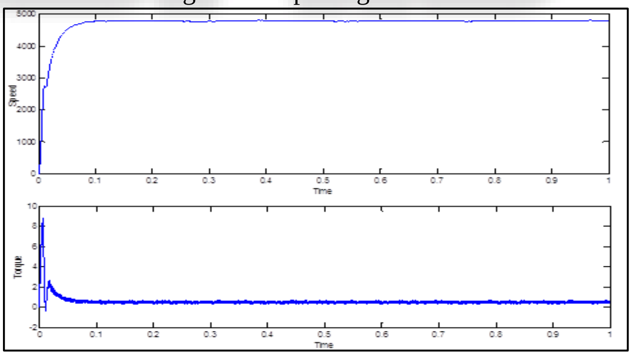

Fig. 5: Speed- Torque waveform (Without load torque)

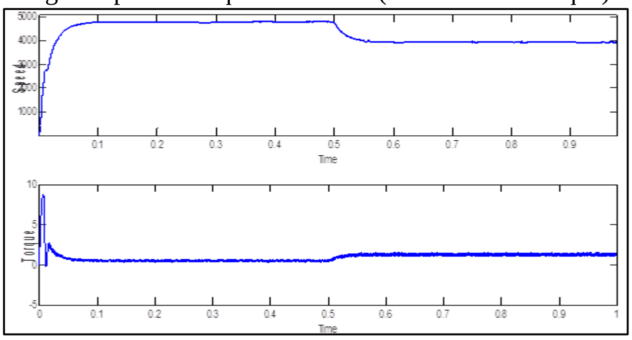

Fig. 6: Speed- Torque waveform (With load torque of 0.8N.m at t=0.5s)

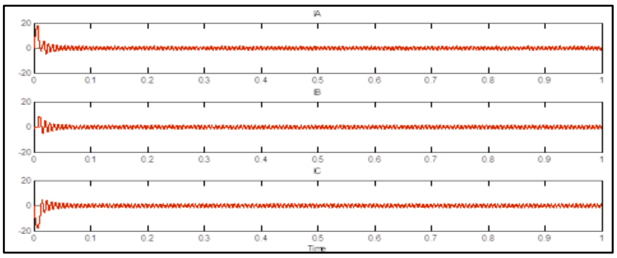

Fig. 7: stator current waveform (without load torque)

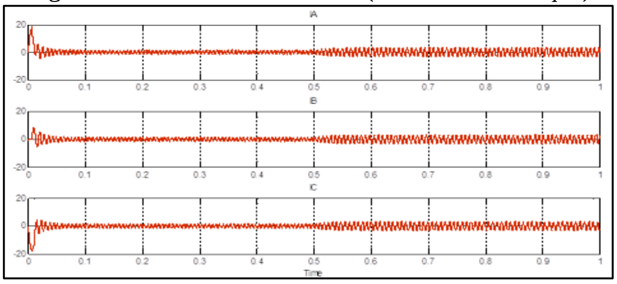

Fig. 8: stator current waveform(with load torque

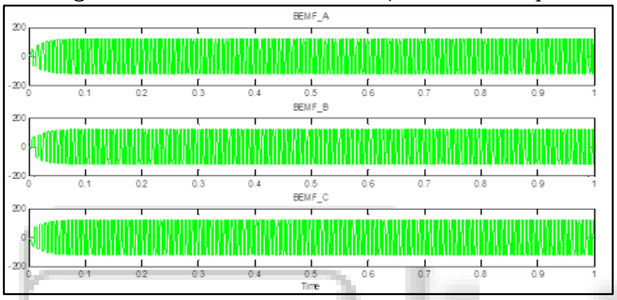

Fig. 9: Back emf waveform (without load torque)

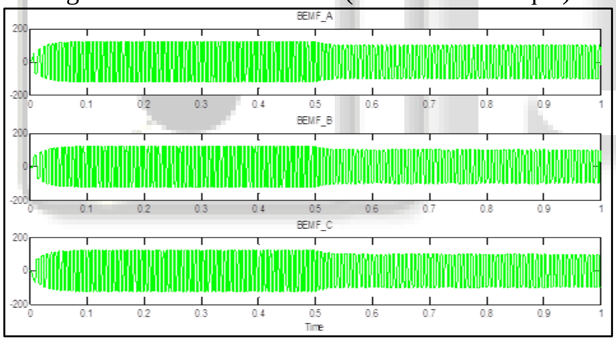

Fig. 10: Back emf waveform (with load torque)

V. CONCLUSION

The BLDC motor MATLAB simulation model presented from which we conclude that motor operates during without load condition with synchronous speed but when load applied there were a speed drop, to overcome this problem controller must be required.

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