Speed control of Brushless DC motor with DSP controller using Matlab

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Abstract—**The paper proposes the development of BLDC motor characteristics using a digital signal processor (DSP) motion control kit (MCK28335 kit) compare real results with simulation results.**
Keywords— BLDC Motor, MCK28335, DSP, Speed

I.   INTRODUCTION

The Brushless DC (BLDC) motor is rapidly gaining popularity by its utilization in various industries, such as appliances, automotive, aerospace, consumer, medical, industrial automation equipment and instrumentation. As the name implies, the BLDC motors do not use brushes for commutation; instead they are electronically commuted.. BLDC motors have many advantages over brushed DC motors and induction motors, a few of these are: [1]

   a.   Better speed Vs torque characteristics
   b.   High dynamic response
   c.   High efficiency
   d.   Long operating life
   e.   Noiseless operation

Before now, several simulation models have been proposed for the analysis of BLDC motors drives. In this paper we propose a simulation model of a BLDC motor without using a controller, whose characteristics are compared with a model with Integral and Proportional controller. In this model the trapezoidal back EMF waveforms are modeled as a function of rotor position and the switching function concept is adopted to model the Voltage source inverter (VSI). This in turn results in obtaining the detailed voltage and current waveforms of the inverter.

Therefore, it can be expected that the developed simulation model can be an easy-to-design tool for the development of BLDC motor drives including control algorithms and topological variations with reduced computation time.

II. CONSTRUCTION AND OPERATING PRINCIPLE

The BLDC motor is also referred to as an electronically commuted motor and, as there are no brushes on the rotor the

commutation is performed electronically depending on the rotor position. The stator phase windings are inserted in the slots or can be wound as one coil on the magnetic pole. Figure 1 shows the basic configuration of BLDC motor with converter circuit.
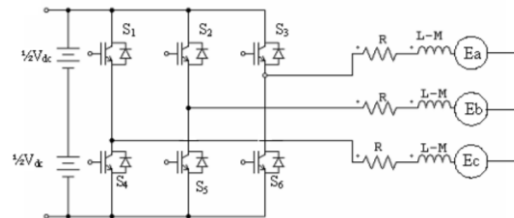

Fig.1: Configuration of BLDC motor with converter circuit

In DC Commutator motor, the current polarity is reversed by the commutator and the brushes, but in the brushless DC motor, the polarity reversal is performed by semiconductor switches which are to be switched in synchronization with the rotor position. Besides the higher reliability, the missing commutator brings another advantage. The commutator is also a limiting factor in the maximal speed of the DC motor. Therefore the BLDC motor can be employed in applications requiring high speed.

Replacement of a DC motor by a BLDC motor place higher demands on control algorithm and control circuit. Firstly, the BLDC motor is usually considered as a three phase system. Thus, it has to be powered by a three phase power supply. Next, the rotor position must be known at certain angles, in order to align the applied voltage with the back-EMF. The alignment between the back-EMF and commutation events is very important. In this condition the motor behaves as a DC motor and runs at the best working point. But the drawbacks of the BLDC motor caused by necessity of power converter and rotor position measurement are balanced by excellent performance and reliability, and also by the ever-falling prices of power components and control circuits.

III.   MATHEMATICAL MODEL OF THE BLDC MOTOR

Modeling of a BLDC motor can be developed in the similar manner as a three-phase synchronous machine. Since there is a permanent magnet mounted on the rotor, some dynamic characteristics are different. Flux linkage from the rotor depends upon the magnet material. Therefore, saturation of magnetic flux linkage is typical for this kind of motors. As any typical three-phase motors, one structure of the BLDC motor is fed by a three-phase voltage source. The source is not necessarily to be sinusoidal. Square wave or other wave-shape can be applied as long as the peak voltage does not exceed the maximum voltage limit of the motor. Similarly, the model of the armature winding for the BLDC motor is expressed as follows:

$$V_a = Ri_a + L\frac{di_a}{dt} + e_a \qquad (1)$$

$$V_b = Ri_b + L\frac{di_b}{dt} + e_b \qquad (2)$$

$$V_c = Ri_c + L\frac{di_c}{dt} + e_c \qquad (3)$$

where
L is armature self inductance [H],
R is armature resistance [Ω],
V_a, V_b, V_c are terminal phase voltage [V],
i_a, i_b, i_c are motor input current [A],
and e_a, e_b, e_c are motor back emf [V].

In the 3-phase BLDC motor, the back-EMF is related to a function of rotor position and the back-EMF of each phase has 120° phase angle difference so equation of each phase should be as follows:

$$e_a = K_w f(\theta)\omega \qquad (4)$$
$$e_b = K_w f(\theta - 2\pi/3)\omega \qquad (5)$$
$$e_c = K_w f(\theta + 2\pi/3)\omega \qquad (6)$$

where
K_w is back EMF constant of one phase [V/rad.s^{-1}],
θ is the electrical rotor angle [°e1.],
ω is the rotor speed [rad.s^{-1}].

The electrical rotor angle is equal to the mechanical rotor angle multiplied by the number of pole pairs p:

$$\theta = \frac{p}{2}\theta_m \qquad (7)$$

where
θ_m is mechanical rotor angle [rad].

Total torque output can be represented as summation of that of each phase. Next equation represents the total torque output:

$$T_e = \frac{e_a i_a + e_b i_b + e_c i_c}{\omega} \qquad (8)$$

where
T_e is the total torque output [Nm],

The equation of mechanical part is represented as follows:

$$T_e - T_l = J\frac{d\omega}{dt} + B\omega \qquad (9)$$

where
T_l is load torque [Nm],
J – inertia of rotor and couple shaft [Kgm^2],
B – friction constant [Nms.rad^{-1}].

The converter block was developed using equations below: [2]

$$V_a = (S_1)V_d/2 - (S_4)V_d/2 \qquad (10)$$
$$V_b = (S_3)V_d/2 - (S_6)V_d/2 \qquad (11)$$
$$V_c = (S_5)V_d/2 - (S_2)V_d/2 \qquad (12)$$

IV.   DSP MOTION CONTROL KIT

Hardware and Software overview:
MSK28335 DSC BOARD and MCWIN28335 software platform including. PM50 Power module board includes 3-phase PWM inverter: 36V, 2.1A, upto 25 kHz PWM frequency and Measurement of motor currents in all 3 phases and DC voltage and Supply is12-36 Vdc.
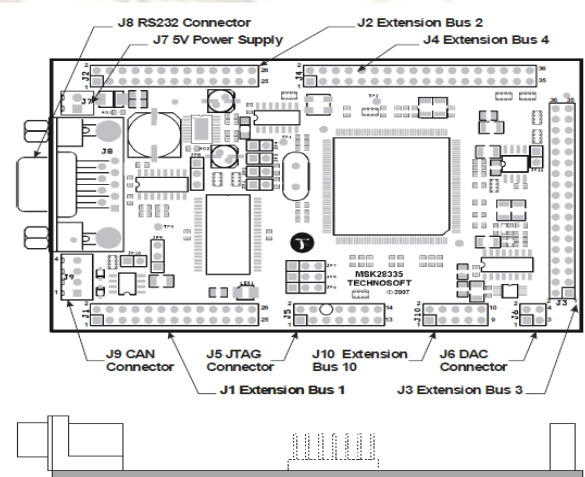

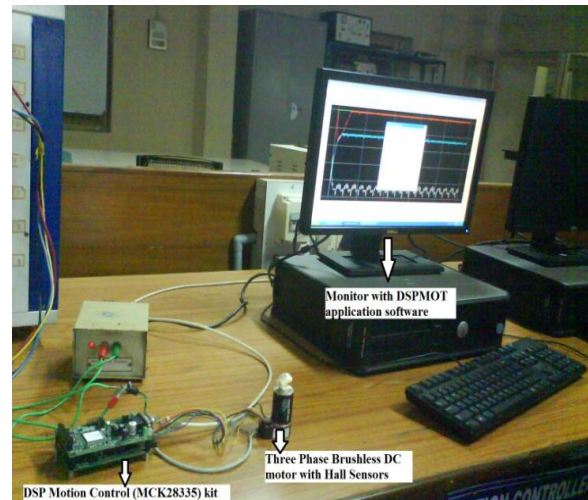Fig.2 : MSK28335 DSC BOARD LAYOUT
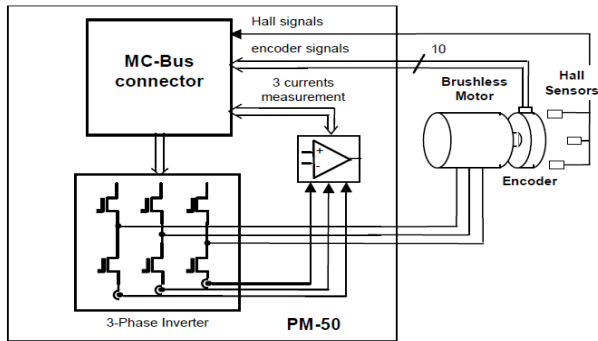

Fig.3: DSP Motion Controlled BLDC motor Kit setup

Fig.4: Block diagram of PM50 Power module

The above block diagrams are MSK28335 DSC BOARD and DSP Motion controlled BLDC motor kit setup and PM50 power module. The MCWIN28335 platform integrates a monitor communication program, as

well as the 'F28335' DSC controller evaluation applications. Using the PC communication module, we can access the MSK28335 board and execute any of these programs. We can integrate modules from these programs into the applications, and use the MCK28335 platform to analyze and evaluate the results.
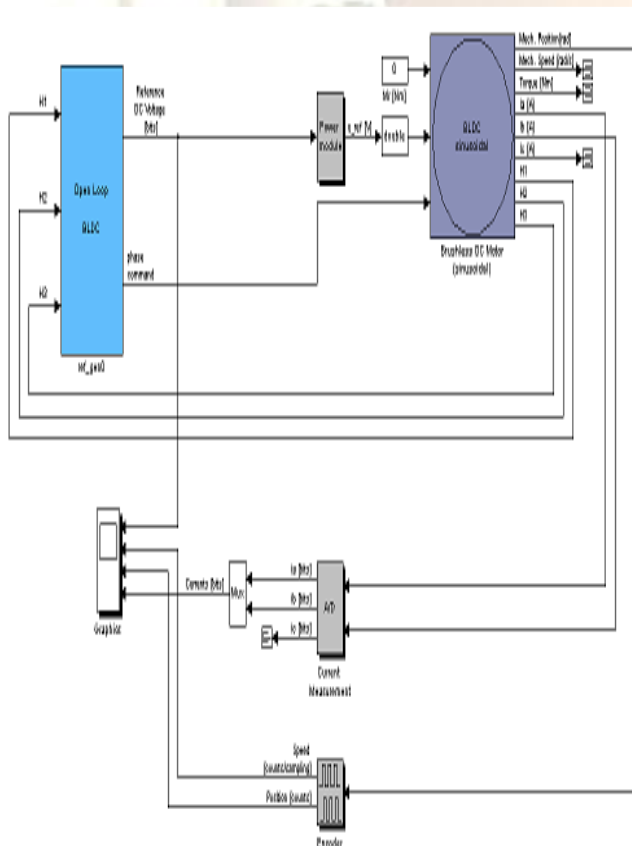
The MCWIN28335 Professional control panel platform contains two ready-to-run motion control applications, for the brushless motor included in the kits. These applications use the DSPMOT program.The MCK28335 kits provide a complete hardware platform for DSC motion control applications evaluation.[2]

The MSK28335 DSC board connected with the PM50 power module, together with the accompanying brushless motor may be used in order to implement complete motion control structures. Thus, it is possible not only to evaluate the DSC controller chip, but also to design and test different motion control algorithms.
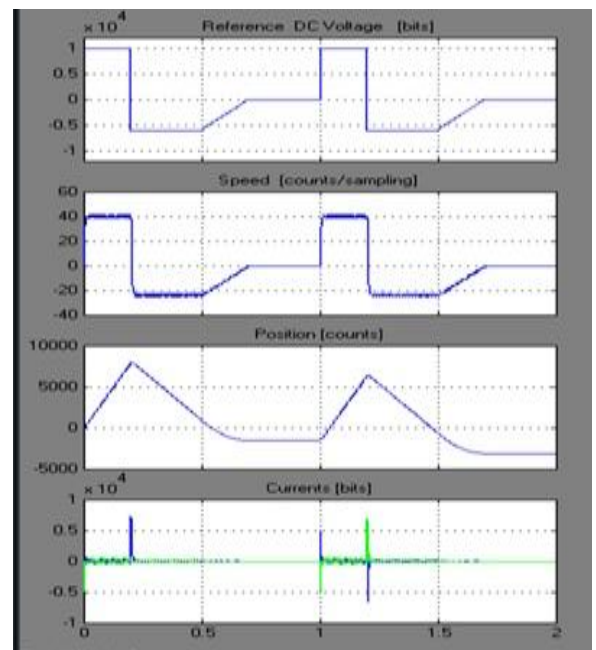
V.   SIMULATION RESULTS

Fig.6: simulation waveforms

Fig.5: Simulink Model of BLDC
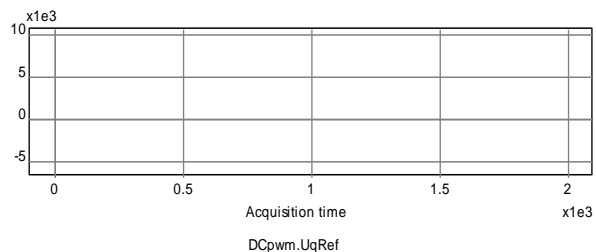
VI. REAL RESULTS (DSP)

Fig.7: Reference DC voltage
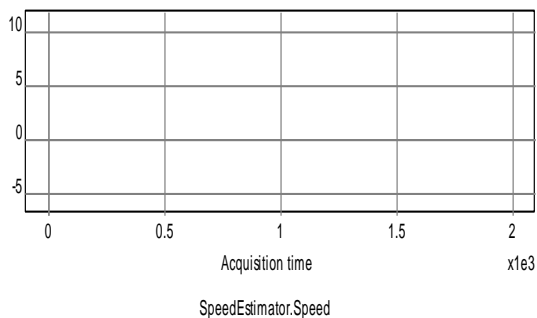
Fig.10: Currents

Fig.8: Speed
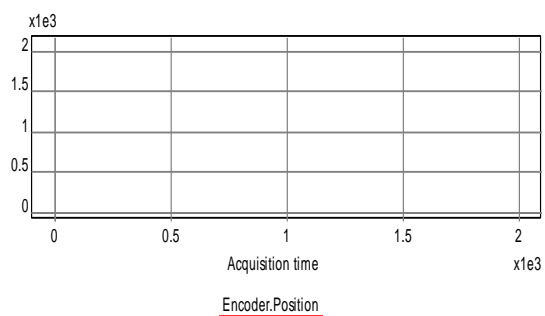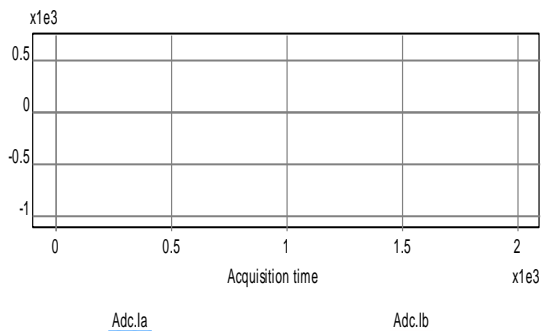
BLDC motor specifications:

Technosoft MBE 300.E500 Brushless motor

1.Coil Dependent Parameter

Phase to Phase Resistance	-	8.61 Ω
Phase to phase inductance	-	0.713 mH
Back EMF constant	-	3.86 V/1000rpm
Torque Constant	-	36.8 mNm/A
Pole Pair	-	1

2. Dynamic Parameters

Rated Voltage	-	36V
No load Current	-	73.2mA
No load Speed	-	9170 rpm
Peak Torque	-	154 mNm

3. Mechanical Parameters

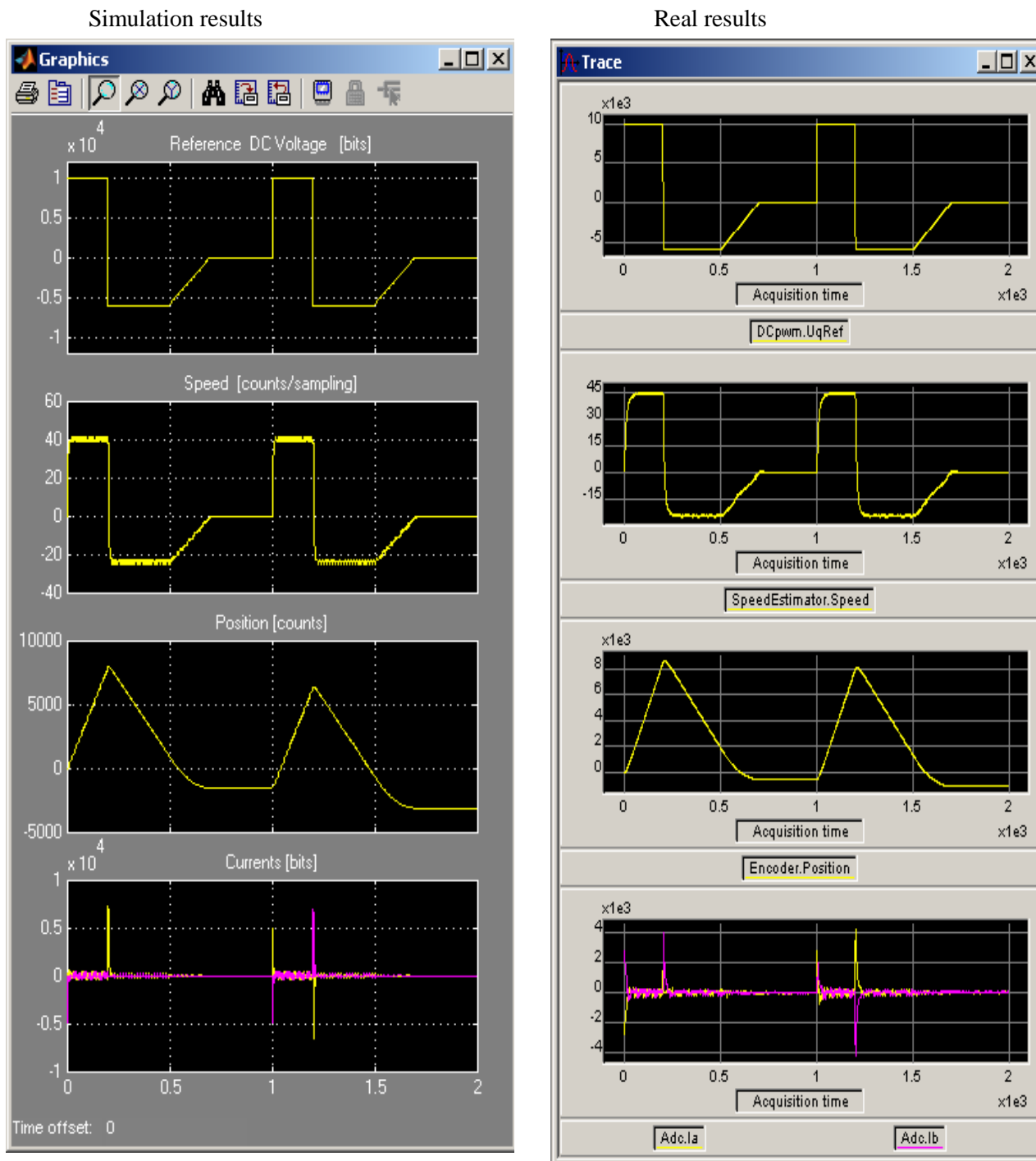|		
Rotor inertia	-	11×10^{-7} Kgm^2
Mechanical time constant	-	7 ms

Fig.9: Position

Simulation results

Real results

Fig.11: Compare simulation results with real results

VII.   CONCLUSION

In this paper, compare real results with simulation results of BLDC motor using MCK28335 kit has been verified. Hence, DSP motion control technique is one of the most efficient and reliable technique that can be applied to control the parameters of the brushless dc motor.

VIII.   REFERENCES

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