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Digital Control of BLDC Motor Using Hall Sensor

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Abstract — **The Brushless DC (BLDC) motor is the ideal choice for applications that require high reliability, high efficiency, and high power-to-volume ratio. BLDC motor are now a days becoming popular in battery operated vehicles, fuel pumps, medical equipments, printers and in many other domestic, industrial and aerospace applications because of its light weight, high operating speed and excellent speed-torque characteristics. The motor is operated in four steady state operating modes of torque-speed plane. To control a BLDC machine it is generally required to measure the speed and position of rotor by using the sensor because the inverter phases, acting at any time, must be commutated depending on the rotor position. Simulation of the proposed model was done using MATLAB/ SIMULINK.**

Key Words — **BLDC (Brush less dc motor), PI controller, Electronic commutator**

I. INTRODUCTION

Brushless DC electric motor (BLDC motors, BL motors) also known as electronically commutated motors (ECMs, EC motors) are synchronous motors that are powered by a DC electric source via an integrated inverter/switching power supply, which produces an AC electric signal to drive the motor. Sensors and electronics control the inverter output amplitude and waveform (and therefore percent of DC bus usage/efficiency) and frequency (i.e. rotor speed) [1].

With a BLDC motor, electrical current powers a permanent magnet that causes the motor to move, so no physical commutator is necessary. The digital controller dsPIC30F4011, which is very advantageous over other controllers, as it combines the calculation capability of Digital Signal Processor and controlling capability

BLDC motor is highly reliable since it does not have any brushes to wear out and replace. When operated in rated conditions, the life expectancy is over 10,000 hours. For long term applications, this can be a tremendous benefit. Although a BLDC motor may cost more than a brushless motor, it will often more than pay for itself in the amount of work time saved.

II. PROPOSED SYSTEM

The control of three phase Brushless DC (BLDC) motor in all the four quadrants using PI controller is proposed here. By using the proposed method, A smooth transition between the quadrants is achieved. The time taken to change the direction of rotation of BLDC motor is also comparatively reduced.

In existed system, the frequent change of direction of rotation and hence the change of quadrants results in frequent braking. During braking time the kinetic energy is wasted as heat energy. Brushless DC Motors are driven by DC voltage but current commutation is controlled by solid state switches. The commutation instants are determined by the rotor position. The rotor shaft position is sensed by a Hall Effect sensor, which provides signals to the respective switches.

Whenever the rotor magnetic poles pass near the Hall sensors, they give a high or low signal, indicating either N or S pole is passing near the sensors. Based on the combination of these three Hall sensor signals, the exact sequence of commutation can be determined. These signals are decoded by combinational logic to provide the firing signals for 120 conduction on each of the three phases.

The BLDC motor is initially made to rotate in clockwise direction, but when the speed reversal command is obtained, the control goes into the clockwise regeneration mode, which brings the rotor to the standstill position. Instead of waiting for the absolute standstill position, continuous energization of the main phase is attempted.

This rapidly slows down the rotor to a standstill position. Therefore, there is the necessity for determining the instant when the rotor of the machine is ideally positioned for reversal.

Hall Effect sensors are used to ascertain the rotor position and from the Hall sensor outputs, it is determined whether the machine has reversed its direction. This is the ideal moment for energizing the stator phase so that the machine can start motoring in the counter clockwise direction.

III. FOUR QUADRANT OPERATION

There are four distinct areas of operation (quadrants), which are based on the directions of operation as well as the mode of operation. The modes are the acceleration and deceleration of the motor.

Two of the quadrants represent the torque application in the direction of motion. The other two quadrants represent the torque being applied in an opposite direction from the motor's motion.

So the motor has two quadrants in which the energy flow is from an electrical flow to a mechanical flow. With the other two, however, the motor acts as a generator. As the motor is in motion, this motion is being converted into electrical power.

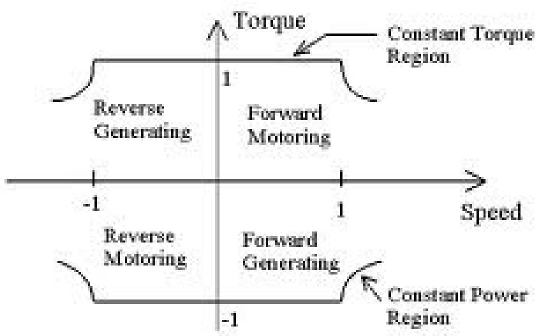


Fig. 1: Speed-Torque characteristic

While many motor drives only operate in one or two quadrants, some offer four quadrant motor controls. This means the drive provides accurate control in both directions by sourcing and sinking the motor's electrical power.

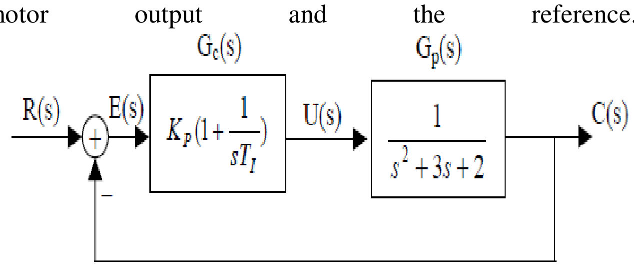
These offer full range speed and torque control for motors with a horsepower rating range of 5 to 300 HP. With four quadrant motor control drives, machinery and motors can run better than ever saving the production costs and reducing long-term profit losses.

Quadrant	Rotation	Torque	Motoring or Regenerating
1	(+)	(+)	Motoring
2	(+)	(-)	Regenerating
3	(-)	(-)	Motoring
4	(-)	(+)	Regenerating

IV. PI CONTROLLER

Proportional action: responds quickly to changes in error deviation.

Integral action: is slower but removes offsets between the motor output and the reference.



$$CLTF = \frac{C(s)}{R(s)} = \frac{K_P(s + 1/T_I)}{s(s^2 + 3s + 2) + sK_P + K_P/T_I}$$

The transfer function of closed loop PI controller is shown above.

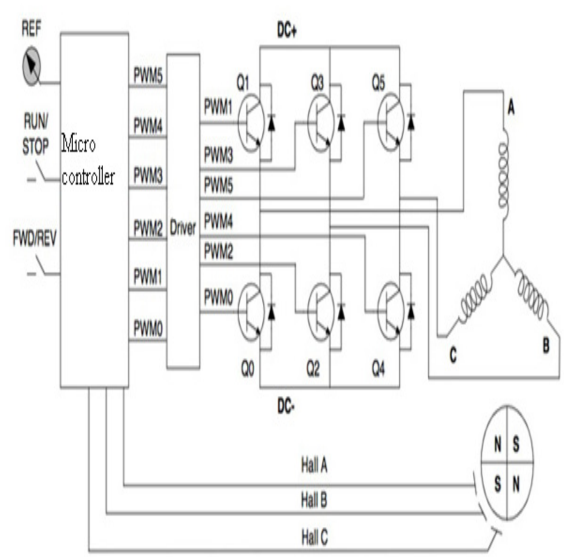
The regulation of speed is accomplished with PI Controller. By increasing the proportional gain of the speed controller, the controller's sensitivity is increased to have faster reaction for small speed regulation errors. This allows a better initial tracking of the speed reference by a faster reaction of the current reference issued by the speed controller.

This will indeed allow a faster reaction to small speed error integral terms that occur when a signal is regulated following a ramp. The controller will react in order to diminish the speed error integral a lot faster by producing a slightly higher accelerating torque when following an accelerating ramp.

Too high gains may also result in saturation. Tuning process is by trial and error method and the Proportional Constant and Integral Constant are 0.1 and 0.03 respectively.

When BLDC motor (Fig. 4) is operating in the first and third quadrant, the supplied voltage is greater than the back emf which is forward motoring and reverse motoring modes respectively, but the direction of current flow differs.

When the motor operates in the second and fourth quadrant the value of the back emf generated by the motor should be greater than the supplied voltage which are the forward braking and reverse braking modes of operation respectively, here again the direction of current flow is reversed.



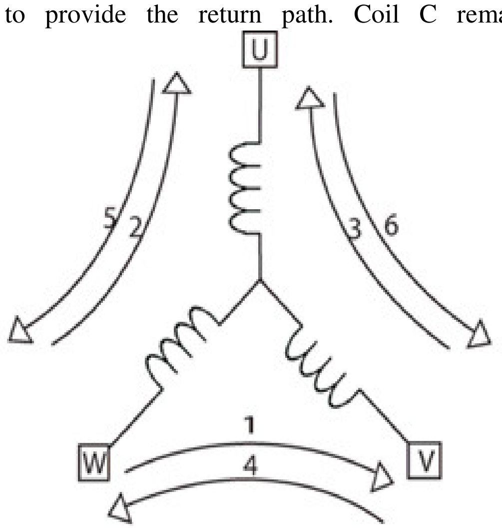
V. HALL EFFECT SENSOR OPERATION

The state of the Hall-effect sensors determines when and how the coils are energized. A pair of Hall-effect sensors is linked to each coil.

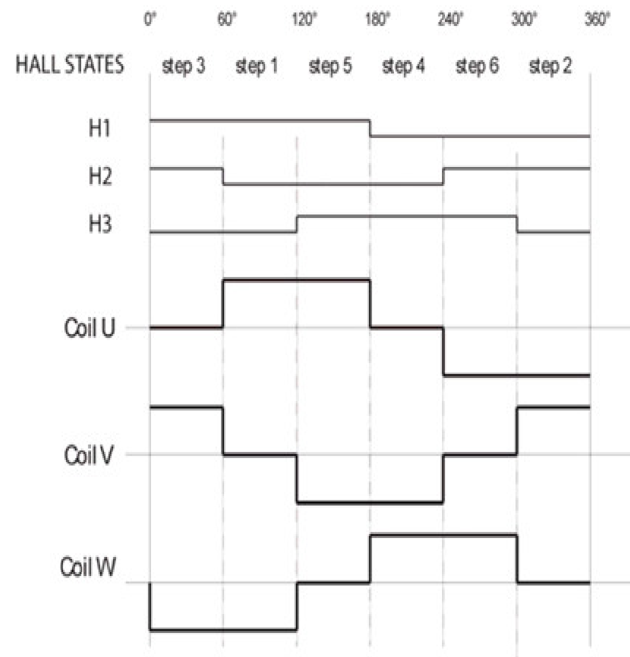
A pair of Hall-effect sensors determines when the microcontroller energizes a coil. In this example, sensors H1 and H2 determine the switching of coil U.

When H2 detects a N magnet pole, coil U is positively energized; when H1 detects a N magnet pole, coil U is switched open; when H2 detects a S magnet pole coil U is switched negative, and finally, when H1 detects a S magnet pole, coil U is again switched open. Similarly, sensors H2 and H3 determine the energizing of coil V, with H1 and H3 looking after coil W.

At each step, two phases are on with one phase feeding current to the motor, and the other providing a current return path. The other phase is open. The microcontroller controls which two of the switches in the three-phase inverter must be closed to positively or negatively energize the two active coils. For example, switching Q1 in Figure 3 positively energizes coil A and switching Q2 negatively energizes coil B to provide the return path. Coil C remains open.



Coil-energizing sequence for one electrical revolution of a three-phase BLDC motor.



The state of the Hall-effect sensors

VI. SIMULINK RESULTS

B.STATE OF CHARGE +VE

FIG.7 STATE OF CHARGE VERY LOW FOR MOTORING OPERATION

D.TORQUE+VE:

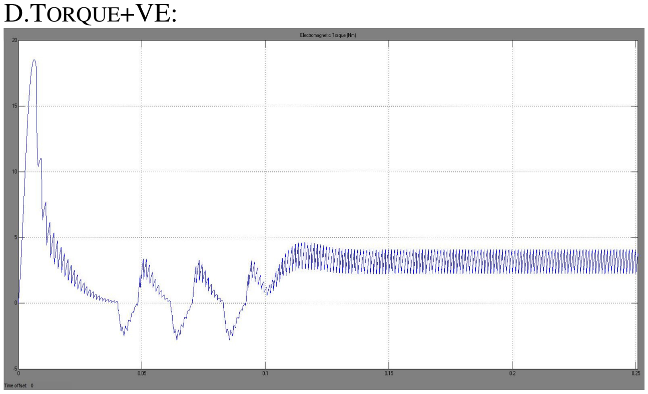


FIG.8 ELECTROMAGNETIC TORQUE REACHING ITS STEADY STATE

VII. CONCLUSION

In this paper, a control scheme is proposed for BLDC motor to change the direction from CW to CCW and the speed control is achieved both for servo response and regulator response. The modelling procedure presented in this paper helps in simulation of BLDC drive system for four quadrant operation. The performance evaluation results show that, such a modelling is very useful in studying the drive system before taking up the dedicated controller design The motor reverses its direction almost instantaneously, it will pass through zero, but the transition is too quick. The time taken to achieve this braking is comparatively less. The generated voltage during the regenerative mode can be returned back to the supply mains which will result in considerable saving of power.

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