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Brushless DC motor Drive during Speed regulation with Current Controller

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ABSTRACT
Brushless DC Motor (BLDC) is one of the best electrical drives that have increasing popularity, due to their high efficiency, reliability, good dynamic response and very low maintenance. Due to the increasing demand for compact & reliable motors and the evolution of low cost power semiconductor switches and permanent magnet (PM) materials, brushless DC motors become popular in every application from home appliances to aerospace industry. The conventional techniques for controlling the stator phase current in a brushless DC drive are practically effective in low speed and cannot reduce the commutation torque ripple in high speed range. This paper presents the PI controller for speed control of BLDC motor. The output of the PI controllers is summed and is given as the input to the current controller. The BLDC motor is fed from the inverter where the rotor position and current controller is the input. The complete model of the proposed drive system is developed and simulated using MATLAB/Simulink software. The operation principle of using component is analysed and the simulation results are presented in this to verify the theoretical analysis.

Keywords - *Bldcm- Brushless Direct Current Motor, Pm- Permanent Magnet, Pi- Proportional Integrated Controller.*

I.   INTRODUCTION

The increase in energy prices spurs higher demands of variable speed PM motor drives. Also, recent rapid proliferation of motor drives into the automobile industry, based on hybrid drives, generates a serious demand for high efficient PM motor drives, and this was the beginning of interest in BLDC motors. BLDC motors, also called Permanent Magnet DC Synchronous motors, are one of the motor type that have more rapidly gained popularity, mainly because of their better characteristics an performance [2]. These motors are used in a great amount of industrial sectors because their architecture is suitable for any safety critical applications. In general, the overall system consists of three parts: (1) power conversion three phase inverters, (2) BLDC motor and load, (3) speed, torque, and current controllers and (4) Position Control by using sensors. Therefore, exact understanding of each part is a prerequisite for analysis and prediction of the overall system operation. Several simulation models have been proposed for the analysis of BLDC motor drives. These models are based on state-space equations, Fourier series, and the d-q axis model [1-6].The brushless DC motor is a synchronous electric motor that, from a modeling perspective, looks exactly like a DC motor, having a linear relationship between current and torque, voltage and speed (rad/sec). It is an electronically controlled commutation system, instead of having a mechanical commutation, which is typical of brushed motors. Additionally, the electromagnets do not move, the permanent magnets rotate and the armature remains static. This gets around the problem of how to transfer current to a moving armature. In order to do this, the brush-system/commutator assembly is replaced by an intelligent electronic controller, which performs the same power distribution as a brushed DC motor [3]. BLDC motors have many advantages over brushed DC motors and induction motors, such as a better speed versus torque characteristics, high dynamic response, high efficiency and reliability, long operating life (no brush erosion), noiseless operation, higher speed ranges, and reduction of electromagnetic interference (EMI).

The control of BLDC motors can be done in sensor or sensorless mode, but to reduce overall cost of actuating devices, sensorless control techniques are normally used. The advantage of sensorless BLDC motor control is that the sensing part can be omitted, and thus overall costs can be considerably reduced. The disadvantages of sensorless control are higher requirements for control algorithms and more complicated electronics [3]. All of the electrical motors that do not require an electrical connection (made with brushes) between stationary and rotating parts can be considered as brushless permanent magnet (PM) machines [4], which can be categorized based on the PMs mounting and the back-EMF shape. The PMs can be surface mounted on the rotor (SMPM) or installed inside of the rotor (IPM) [5],

and the back-EMF shape can either be sinusoidal or trapezoidal. A PMAC motor is typically excited by a three-phase sinusoidal current, and a BLDC motor is usually powered by a set of currents having a quasi-square waveform [6]. Brushless DC motors were developed from conventional brushed DC motors with the availability of solid state power semiconductors. Brushless DC motors are similar to AC synchronous motors. The major difference is that synchronous motors develop a sinusoidal back EMF, as compared to a rectangular, or trapezoidal, back EMF for brushless DC motors. Both have stator created rotating magnetic fields producing torque in a magnetic rotor. The remainder of the paper is arranged as follows. Section -2 discussAnalysis of BLDC motor drive system. Next, section -3 explains the problem identification in bldc motor drive, in this section we discuss problem related to position and speed control of BLDC motors drive using sensors and also describeproblems occur in selecting the value of PI controller gain Section -4 , discuss methodology of BLDC motor drive. Finally in section -5 shows the results analysis of BLDC motor drive and conclusion.

II. PROPOSED CONCEPT OF BLDC MOTOR DRIVE

Figure 1 shows the overall system configuration of the three-phase BLDC motor drive. The three phase inverter topology is a six-switch voltage-source configuration with constant dc-link voltage (Vdc), which is identical with the induction motor drives and the permanent magnet ac motor drives. The analysis is based on the following assumption for simplification [12]: 1. The motor is not saturated. 2. Stator resistances of all the windings are equal, and self- and mutual inductances are constant. 3. Power semiconductor devices in the inverter are ideal. 4. Iron losses are negligible.
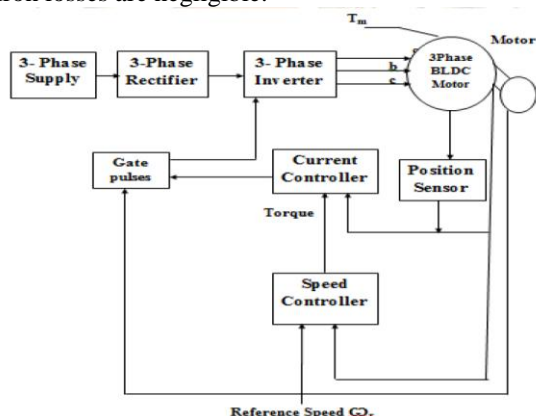

Figure.1: Speed regulation of BLDC motor.

The high-level schematic shown below is built from six main blocks. The PMSM, the three-phase inverter, and the three-phase diode rectifier models are provided with the SimPowerSystems library. The

speed controller, the braking chopper, and the current controller models are specific to the Electric Drives library. It is possible to use a simplified version of the drive containing an average-value model of the inverter for faster simulation. The speed controller, the braking chopper, and the current controller models are specific to the Electric Drives library. It is possible to use a simplified version of the drive containing an average-value model of the inverter for faster simulation.

III. SPEED CONTROLLER

The speed controller is based on a PI controller, shown above. The output of this controller is a torque set point applied to the current controller block. Conventional PI controller is used as a speed controller for recovering the actual motor speed to the reference. The reference and the measured speed are the input signals to the PI controller. The KP and KI values of the controller are determined by trial and error method for set speed. The controller output is limited to give the reference torque, Its integral term has the effects of accumulation, memorization and delay, which enables PI controller to remove static error. The Saturation block limits the amplitude of outputting three phase reference current to the demanding range.
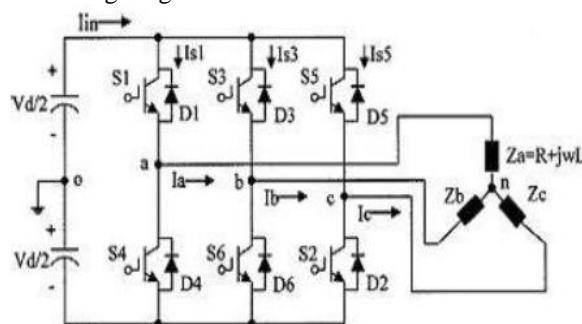

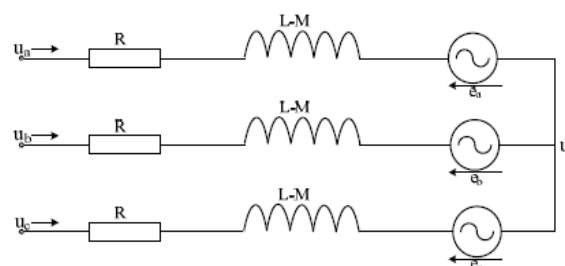Figure.2: Three converter connected to BLDC.

Figure.3: The Equivalent circuit of BLDC machine.

IV. CURRENT CONTROLLER

In the BLDC motor drive, duty cycle controlled voltage PWM technique and hysteresis current control technique can be regarded as the main current control strategies. In this thesis bipolar hysteresis current control is used for obtaining the fast dynamic responses during transient states.
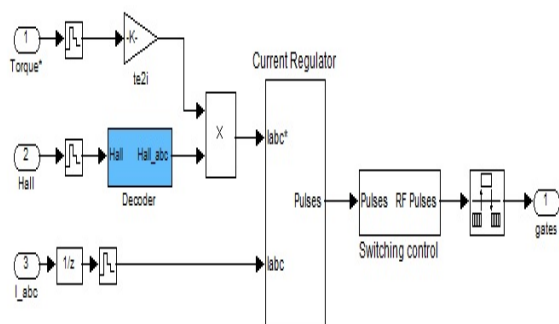
Figure.4: Current Controller MATLAB/SIMULINK Diagram.

These kinds of devices are based on Hall-effect theory, which states that if an electric current-carrying conductor is kept in a magnetic field, the magnetic field exerts a transverse force on the moving charge carriers that tends to push them to one side of the conductor. A build-up of charge at the sides of the conductors will balance this magnetic influence producing a measurable voltage between the two sides of the conductor. To rotate the BLDC motor the stator windings should be energized in a sequence. It is important to know the rotor position in order to understand which winding will be energized following the energizing sequence. Rotor position is sensed using Hall-effect sensors embedded into the stator The connecting principle between the brushless motor and this sensor is reminiscent of the miniaturized magnetic angular encoder based on 3-D Hall sensors. A permanent magnet is fixed at the end of a rotary shaft and the magnetic sensor is placed below, and the magnet creates a magnetic field parallel to the sensor surface. This surface corresponds to the sensitive directions of the magnetic sensor. Three-phase brushless motors need three signals with a phase shift of 120° for control, so a closed-loop regulation may be used to improve the motor performance.
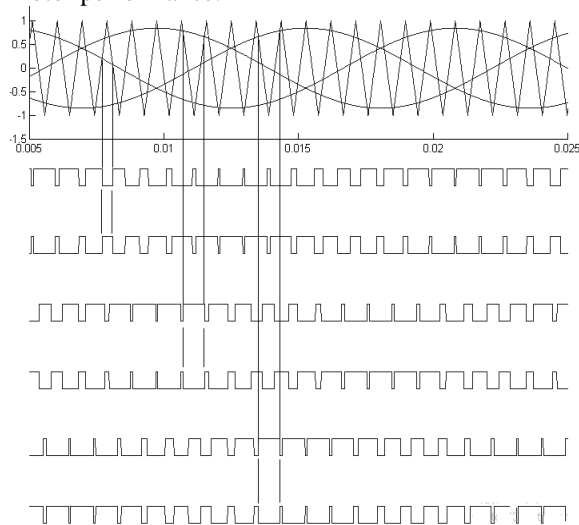
Figure.5: PWM generator in Three Phase converter.

The pulses are generated by comparing a triangular carrier waveform to a reference modulating signal. The modulating signals can be generated by the PWM generator itself, or they can be a vector of external signals connected at the input of the block.

V. MATLAB/SIMULINK AND RESULTS

Simulation of brushless dc motor during no-load condition has been observed. The starting dynamics of the motor is shown in Figure 7. The reference speed is set at 300 rad/sec. The starting current is limited to 7.8A by the controller. The simulation results under no load condition shows the following characteristics. Figure 6, shown the MATLAB/SIMULINK model of proposed concept. When a step load of 1 N-m is suddenly applied, there is small change in the speed, but the controller recovers the speed to set value and there is no appreciable change in back-emf. The simulation results under load condition. The current increases to 8.5 A to meet the extra load with increases in electromagnetic torque to 1.1 N-m.
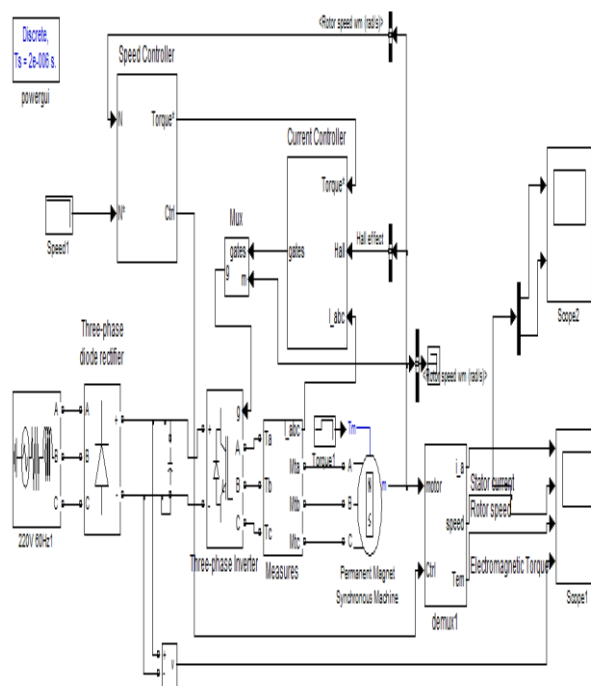
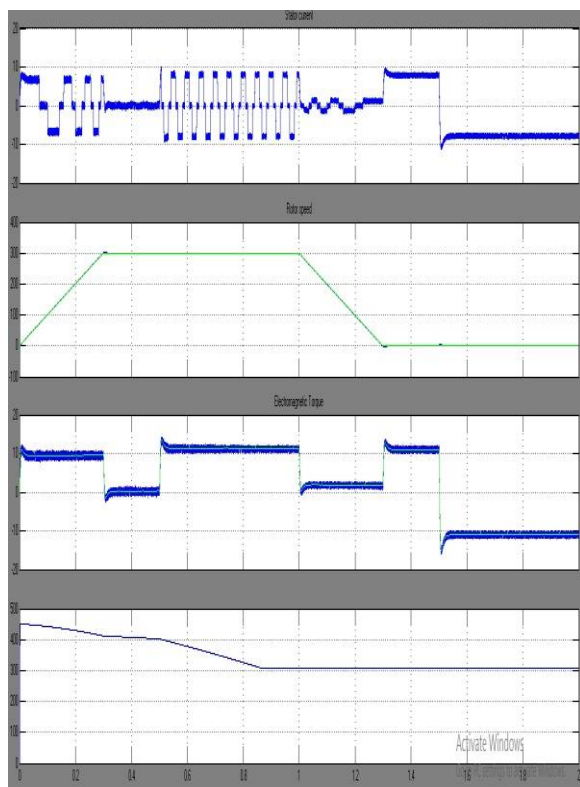Figure.6: BLDC motor drive with current controller.

Figure.7: MATLAB/SIMULINK Results of Proposed concept with reference signals in green color and actual signals in blue color (a) Stator current, (b) Rotor Speed, (c) Electromagnetic torque and (d) DC voltage.

VI. CONCLUSION

In this paper, the simulation of the brushless DC motor was done using the software package MATLAB/SIMULINK. In this paper a review of position control using Hall sensor methods in current controller for BLDC motors has been presented. It is obvious that the control for BLDC motors using position sensors, such as shaft encoders, resolvers or Hall-effect probes, can be improved by means of the elimination of these sensors to further reduce cost and increase reliability. In this paper we have done result analysis and found results in different load conditions. We have also analyzed the steady state condition and transient condition. The steady state speed was found to be very close to the reference speed.

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