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Speed Control of Bldc Motor Drive By Using Pid Controllers

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ABSTRACT

This paper mainly deals with the Brushless DC (BLDC) motor speed driving systems have sprouted in various small scale and large scale applications like automobile industries, domestic appliances etc. This leads to the development in Brushless DC motor (BLDCM). The usage of BLDC Motor enhances various performance factors ranging from higher efficiency, higher torque in low-speed range, high power density ,low maintenance and less noise than other motors. The BLDC Motor can act as an alternative for traditional motors like induction and switched reluctance motors. In this paper PID controller is implemented with speed feedback loop and it is observe that torque ripples are minimized. Simulation is carried out using MATLAB / SIMULINK. The results show that the performance of BLDC Motor is quite satisfactory for various loading conditions. Brushless DC motor drives are typically employed in speed controlled applications.

Key words: PID, PI, BLDC, MATLAB/SIMULINK

I. INTRODUCTION

Brushless DC (BLDC) motors are synchronous motors with permanent magnets on the rotor and armature windings on the stator. Hence, from a construction point of view, they are the inside-out version of DC motors, which have permanent magnets or field windings on the stator and armature windings on the rotor.

The most obvious advantage of the brushless configuration is the removal of the brushes, which eliminates brush maintenance and the sparking associated with them. Having the armature windings on the stator helps the conduction of heat from the windings. Because there are no windings on the rotor, electrical losses in the rotor are minimal. The BLDC motor compares favorably with induction motors in the fractional horsepower range. The former will have better efficiency and better power factor and, therefore, a greater output power for the same frame, because the field excitation is contributed by the permanent magnets and does not have to be supplied by the armature current. These advantages of the BLDC motor come at the expense of increased complexity in the electronic controller and the need for shaft position sensing. Permanent magnet (PM) excitation is more viable in smaller motors, usually below 20 kW. In larger motors, the cost and weight of the magnets become excessive, and it would make more sense to opt for excitation by electromagnetic or induction means. However, with the development of high-field PM materials, PM motors with ratings of a few megawatts have been built. The direct torque control (DTC) techniques, implemented in six-switch inverter, for brushless dc (BLDC) motors with non-sinusoidal back-EMF using two and three-phase conduction modes. First of all, the classical direct torque control of permanent magnet synchronous motor (PMSM) with sinusoidal back-EMF is discussed in detail. Secondly, the proposed two-phase conduction mode for DTC of BLDC motors is introduced in the constant torque region. In this control scheme, only two phases conduct at any instant of time using a six-switch inverter. By properly selecting the inverter voltage space vectors of the two-phase conduction mode from a simple look-up table the desired quasi-square wave current is obtained. Therefore, it is possible to achieve DTC of a BLDC motor drive with faster torque response while the stator flux linkage amplitude is deliberately kept almost constant by ignoring the flux control in the constant torque region. Direct Torque Control (DTC) is the direct control of torque and stator flux of a drive by inverter voltage space vector selection through a look up table. A relationship is established between the torque, the flux and the optimal inverter switching so as to achieve a fast torque response and reduced torque ripple. It exhibits better dynamic performance than conventional control methods, less sensitive to parameter variations and is simpler to implement. The speed control loop of DTC should be cautiously designed to improve the dynamics of brushless dc (BLDC) motor drive for high performance applications. It is not easy to formal an exact mathematical model of BLDC motor.

Mathematical Modeling of BLDC

The non-sinusoidal nature of the back-emf and current waveforms, transformation of the machine equations to the *d-q* model is cumbersome, and it is easier to use the phase-variable approach for modeling and simulation. The back-emf can be represented as a Fourier series or by using piecewise linear curves. The circuit equations of the three windings in phase variables can be written as

$$\begin{bmatrix} Va \\ Vb \\ Vc \end{bmatrix} = \begin{bmatrix} R & 0 & 0 \\ 0 & R & 0 \\ 0 & 0 & R \end{bmatrix} \begin{bmatrix} ia \\ ib \\ ic \end{bmatrix} + \begin{bmatrix} L-M & 0 & 0 \\ 0 & L-M & 0 \\ 0 & 0 & L-M \end{bmatrix} \frac{d}{dt} \begin{bmatrix} ia \\ ib \\ ic \end{bmatrix} + \begin{bmatrix} ea \\ eb \\ ec \end{bmatrix}$$

Where, Va,Vb,Vc are the phase voltages, ia,ib,ic are the phase currents, *ea*,*eb*,*ec* are the phase back-emf voltages is the phase resistance, *L* is the self-inductance of each phase, and *M* is the mutual inductance between any two phases. The electromagnetic torque is given by

$$Te= (e_a i_a+e_b i_b+e_c i_c w_m$$

Where W*m* is the mechanical speed of the rotor. The equation of motion is

$$\frac{d}{dt}Wm = (Te - Tl - BWm)/J$$

Where *TL* is the load torque, *B* is the damping constant, and *J* is the moment of inertia of the drive. The electrical frequency is related to the mechanical speed by

$$We= P2wm$$

Where *P* is the number of rotor poles. In stationary α-β reference frame Te is expressed as

$$Te=\left(\frac{3p}{4}\right)\left[\frac{d\Psi r\alpha}{d\theta e} is\alpha + \frac{d\Psi r\beta}{d\theta e} is\beta\right]$$

Where Ψr α, Ψrβ are the and axes rotor flux linkages and

$$\Psi_{r\alpha} = \Psi_{s\alpha} - L_s\, i_{s\alpha}$$
$$\Psi_{r\beta} = \Psi_{s\beta} - L_s\, i_{s\beta}$$

Where *L*s is the stator winding inductance. The application of BLDC drives is based on the flux linkage observers. The stator flux linkage vector can be obtained from the measured stator voltages and currents by using the following equations.

$$\Psi s=\int(u_s - R\, i_s)\, dt$$

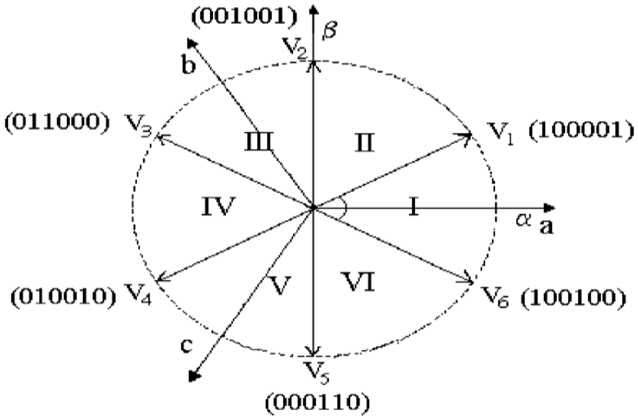
The α and β components of stator flux linkage vector are given by

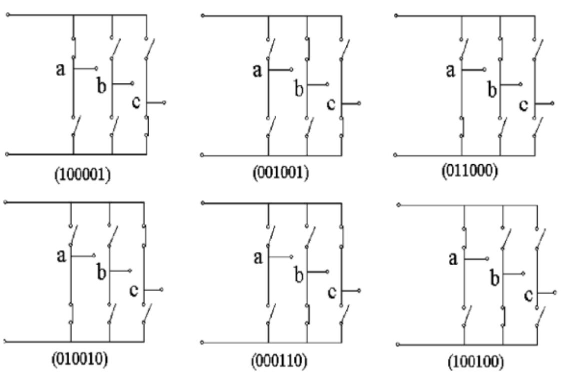
$$\Psi_{s\alpha} =\int(u_{s\alpha} - R\, i_{s\alpha})\, dt$$
$$\Psi_{s\beta} =\int(u_{s\beta} - R\, i_{s\beta})\, dt$$

The magnitude and angular position of the stator flux-linkage vector can be derived from $□_{s\alpha}$ and $□_{s\beta}$ as

$$\Psi=\sqrt{\mathbf{\Psi}^2 \mathbf{s}\alpha + \mathbf{\Psi}^2 \mathbf{s}\beta}$$

In a BLDC drive only two phases are conducting in the120° conduction mode, except during commutation periods when all three phases conduct, the unexcited phase conducting through the freewheeling diode. Since the upper and lower switches in the same phase leg may both be simultaneously off in BLDC drive, six digits are required to represent the states of the inverter switches one digit for each switch. Thus the voltage space vectors v1, v2, v3, v4, v5 andv6 are represented as switching signals (100001), (001001), (011000), (010010), (000110) and (100100) respectively, where from left to right, the logical values express the states of the upper and lower switching signals for phases A, B, C respectively. The zero voltage space vector is defined as(000000).





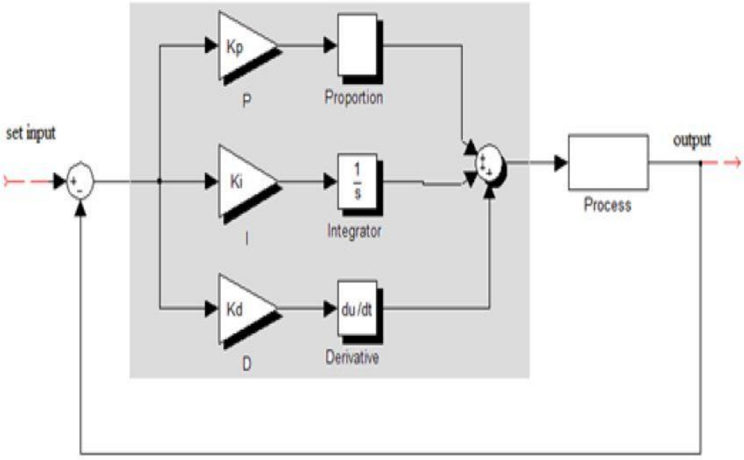
II. PID CONTROLLER

The family of PID controllers is constructed from various combinations of the proportional, integral and derivative terms as required to meet specific performance requirements. The formula for the basic parallel PID controller is (Transfer function PID controller formula)

$$U_c(t)=[K_p+K_i\frac{1}{s}+K_dS]\ E(s)$$

Time-domain PID controller formula

$$Uc(t)=K_pe(t)+K\int_I^t e(t)dT+K_d\frac{de}{dt}$$



III. SIMULATION BLOCK

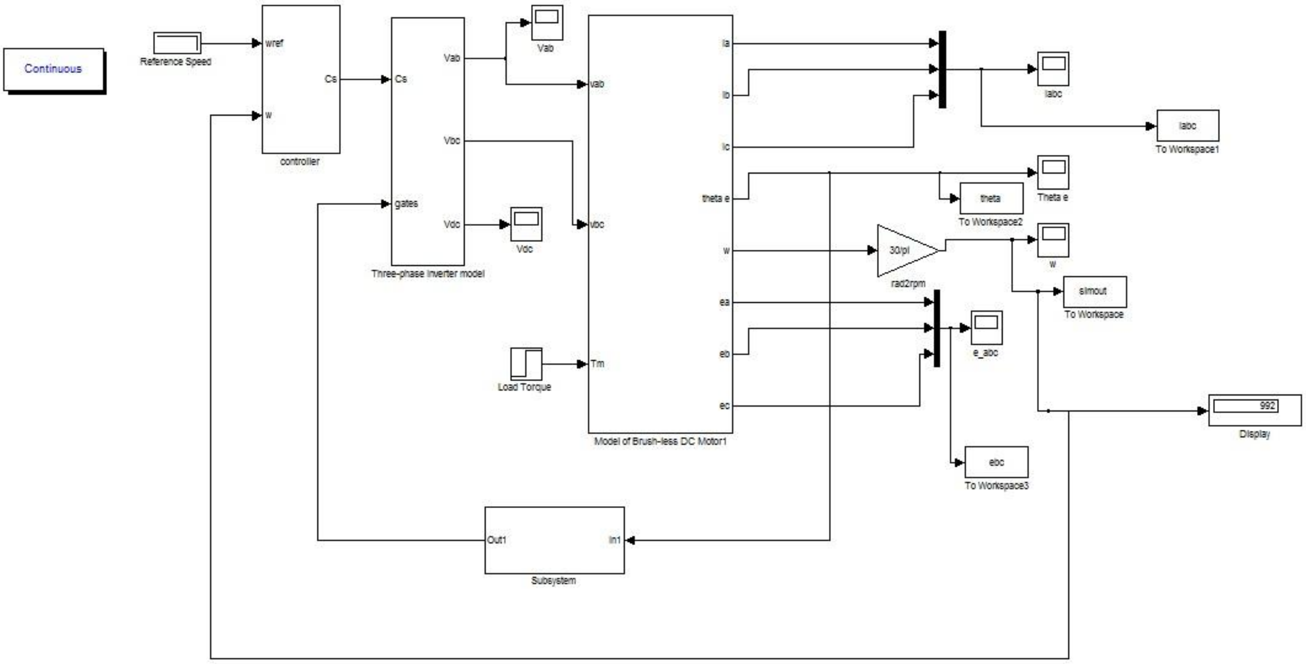


Fig 1 .SIMULATION MODEL OF PID CONTROLLER BLDC DRIVE

IV. SIMULATION RESULTS

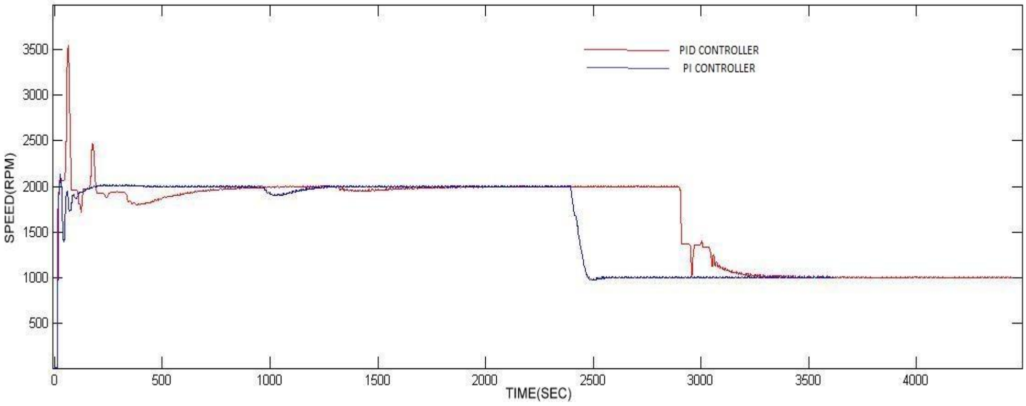


Fig 2.RESPONSE OF SPEED DURING LOAD CHANGES.

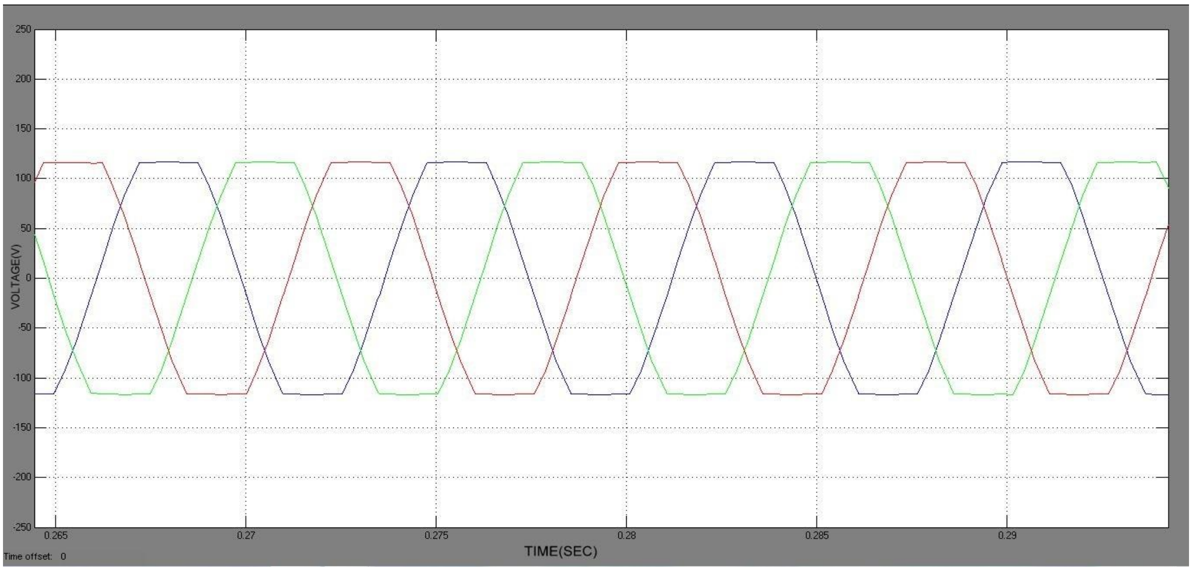


Fig 3: RESPONSE OF VOLTAGE DURING LOAD CHANGES

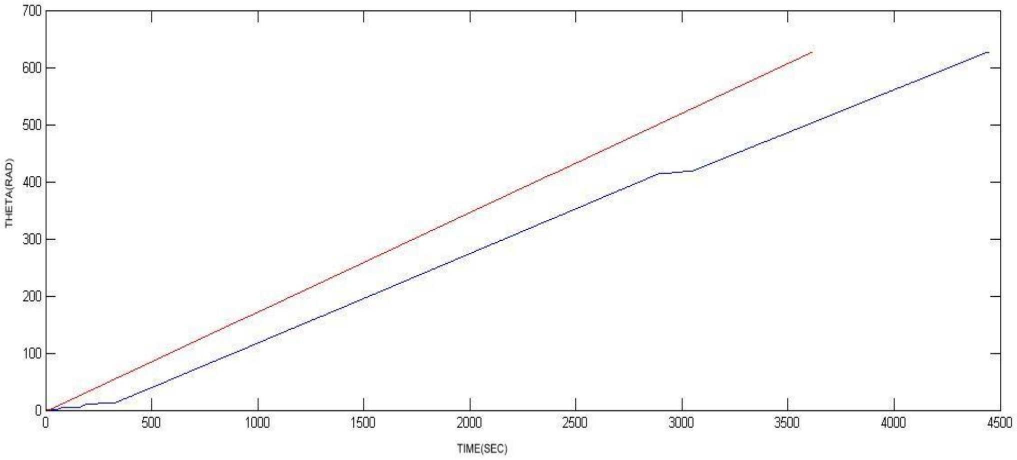


Fig 4: TORQUE RESPONSE DURING LOAD CHANGES

V. CONCLUSION

By comparing the performances of Permanent-magnet brushless dc motor with PI and PID controller it is concluded that PID response gives high efficiency. Due to this high efficiency, higher torque will be produced in low-speed range, and it has high power density, low maintenance and less noise than other motors. In this paper closed loop speed control of BLDC motor drive with PID controller loop is carried out and it is compared with PI controller fed BLDC drive. Simulation results shows that current ripple and torque ripple are minimized which enhance the performance of the drive. The results show that the dynamic performance of the motor is quite satisfactory for various loading conditions.

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