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A THREE PHASE SENSOR LESS FIELD ORIENTED CONTROL FOR BLDC MOTOR

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Abstract--- *This paper presents a three phase sensor less field oriented control for BLDC motor. The proposed sensor less control technique gives the simple and high-performance motor drive. With In addition maximum torque per ampere block is implemented to optimize torque generation efficiency without power factor angle calculation. The space vector modulation (SVPWM) of Brushless DC motor (BLDC) is different from that of permanent magnet synchronous motor for its turn-off phase and trapezoidal back electromotive force. To overcome these problems, a SVPWM method is presented in this paper. The application of SVPWM to Brushless AC drives has been investigated extensively. This paper describes its application to BLDC drives and highlights the essential differences in its implementation, as regards torque estimation and the representation of the inverter voltage space vectors, this makes more robust against disturbances. This proposed technique is more preferred for small and medium rating applications. This technique is ideal for applications which require good performance over the wide operating speed rages. It also presents robustness to parameters variation causes by temperature or flux. This paper discusses the theoretical analysis along with simulation results.*

Keywords--- *BLDC motor, Voltage source inverter, Field oriented control, Sensor less control, Space vector modulation.*

I.INTRODUCTION

The advents of high performance magnets, such as samarium cobalt and neodymium boron iron, have made it possible for permanent magnet motor drives to achieve performances that can surpass conventional DC motors and induction motors, and thus are becoming more and more attractive to industrial applications. In comparison with induction motors, PM motors have distinct advantages, including high power density, high torque to inertia ratio, high efficiency, and better controllability. Permanent magnet motor drives can be categorized into two types. The first category, BLDC motor drive, is based on position that is not continuous but at fixed points, typically every 60 electrical degrees for commutation of phase currents. The ideal back EMF is trapezoidal. Correspondingly, BLDC motors adopt six-step trapezoidal control. While the control is simple, easily implemented, and low cost, it can cause torque ripple and noise. Which uses continuous rotor position feedback with sinusoidal voltages and currents generated by PWM modulation of DC bus. Because the ideal back EMF of a BLDC motor is sinusoidal, constant torque with very low ripple is produced. This improves torque ripple, noise and efficiency. Additionally, BLDC motors are suitable for advanced motor control methods like vector control.

High-performance motor control is characterized by smooth rotation over the entire speed range of the motor, full torque control at zero speed, and fast accelerations and decelerations. To achieve such control, use the FOC techniques for 3-phase AC motors. The basic idea of the FOC algorithm is to decompose the stator current into the magnetic field-generating part and the torque-generating part. Both components can be controlled separately after the decomposition. The structure of the motor controller is then as simple as that for separately excited DC motors.

For sensor less field oriented control, a three-phase space voltage is generated and used as a vector to control three-phase stator currents. By transforming physical phase currents into a rotational vector using Clarke and Park transformations, the flux and torque currents become time-invariant, allowing direct control of the motor flux and torque, as for DC motors, and thus achieving fast dynamic response and high performance. By eliminating speed sensor, SVC directly acquires the flux and speed, etc. through observer or estimator after processing the information of terminal voltages and currents. It not only reduces cost of the drive system, but also improves system reliability. The input is a single phase AC power supply -110 volts or 220 volts, which is converted into 160V or 320V DC voltage. The three-phase inverter adopts voltage source inverter (VSI) and uses power modules of 10A, 16A or 20A, which generates three phase voltages with variable frequency and amplitude to drive the motor to the desired voltage. The PWM pattern for the power module is controlled by SH7086 MCU using sensor less vector control technology.

CO-ORDINATE TRANSFORMATION

A series of coordinate transforms, you can indirectly determine and control the time invariant values of torque and flux with classic PI control loops. The process begins by measuring the 3-phase motor currents. In practice, the instantaneous sum of the three current values is zero. Thus by measuring only two of the three currents, you can determine the third. Because of this fact, hardware cost can be reduced by the expense of the third current sensor.

CLARK'S TRANSFORMATION

First coordinate transform, called the Clarke's Transform, moves a three axis, two dimensional coordinate system, referenced to the stator, onto a two axis system, keeping the same reference (where i_a, i_b and i_c are the individual phase currents).

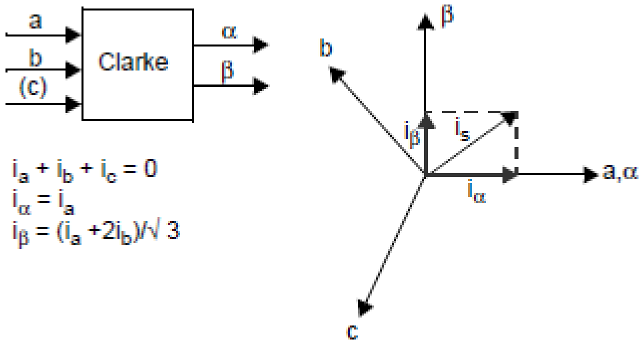

Fig.1.Clark's transformation circuit.

PARK'S TRANSFORMATION

At this point, you have the stator current represented on a two axis orthogonal system with the axis called α-β. The next step is to transform into another two axis system that is rotating with the rotor flux. This transformation uses the Park's Transform, This two axis rotating coordinate system is called the d-q axis. ɵ represents the rotor angle.

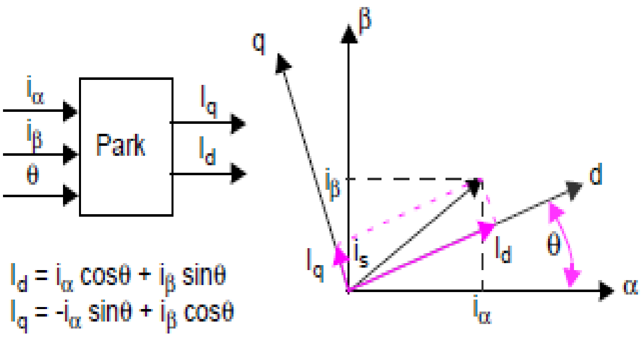

Fig.2. Park's transformation circuit.

INVERSE PARK'S TRANSFORMATION

After the PI iteration you have two voltage component vectors in the rotating d-q axis. You will need to go through complementary inverse transforms to get back to the 3-phase motor voltage. First you transform from the two axis rotating d-q frame to the two axis stationary frame α-β. This transformation uses the Inverse Park's Transform.

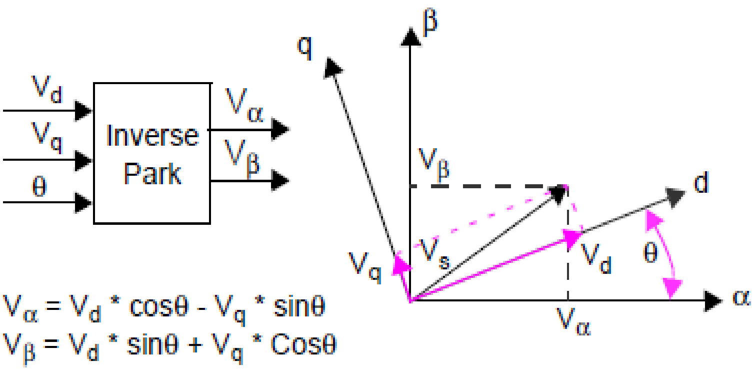

Fig.3. Inverse Park's transformation.

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II. PROPOSED FOC CIRCUIT

The features of the Brush less dc motor (high efficiency, high torque capability, high power density and durability) are attractive for using the motion-control applications. The invention of the vector control algorithm of the AC motors came from the attempt to achieve an AC motor torque/speed characteristic similar to that characteristic of the separately excited DC motor. In the DC motor, the maximum torque is generated automatically because of the mechanical switch called the commutator that feeds current only to that coil, whose position is orthogonal to the direction of the magnetic flux generated by the stator excitation coils.

The BLDC has the inverse construction, the excitation is on the rotor, and the motor has no commutator. Due to the decomposition of the stator current into a magnetic field-generating part and a torque-generating part, it is possible to control these two components independently and to reach the required performance. In order to keep the constant desired torque, the magnetic field generated by the stator coils has to follow the rotor at the same "synchronous" speed. Therefore, to successfully perform the vector control, the rotor shaft position must be known and is one of the key variables in the vector control algorithm.

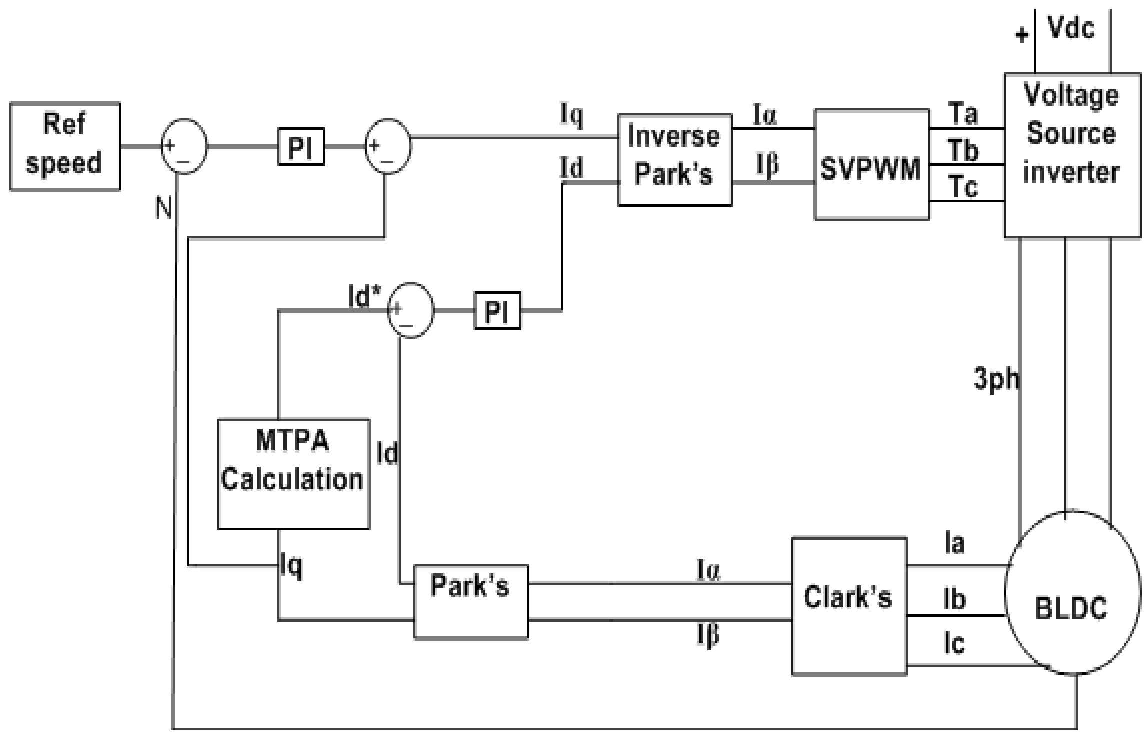

Fig.4 proposed FOC control circuit.

According to the electromagnetic laws, the torque produced in the BLDC motor is equal to vector cross product of the two existing magnetic fields. The torque is maximum if stator and rotor magnetic fields are orthogonal meaning if we are to maintain the load at 90 degrees. If we are able to ensure this condition all the time, if we are able to orient the flux correctly, we reduce the torque ripple and we ensure a better dynamic response. However, the constraint is to know the rotor position: this can be achieved with a position sensor such as incremental encoder. For low-cost application where the rotor is not accessible, different rotor position observer strategies are applied to get rid of position sensor.

In brief, the goal is to maintain the rotor and stator flux in quadrature, the goal is to align the stator flux with the q axis of the rotor flux, i.e. orthogonal to the rotor flux. To do this the stator current component in quadrature with the rotor flux is controlled to generate the commanded torque, and the direct component is set to zero. The direct component of the stator current can be used in some cases for field weakening, which has the effect of opposing the rotor flux, and reducing the back-emf, which allows for operation at higher speeds.

III. CONVERSION CIRCUIT

In this proposed technique using three phase voltage source inverter. Available supply DC but we are connecting BLDC drive, to drive the motor required AC supply that's why we are using three phase voltage source inverter. It converts DC supply to AC. Converting AC supply very small not suitable for to operate the heavy loads.

VOLTAGE SOURCE INVERTER

Three-phase dc-ac inverter is commonly used in the industry. There are many applications in industry that used this type of conversion (dc-ac) in order to operate. In this inverter having six switches T_1,T_2,T_3,T_4,T_5, and T_6, also it having three legs. Every leg require two switches, first leg connecting T_1 and T_4, second leg connecting T_3 and T_6, third leg connecting T_5 and T_2. Every 60^0 conduction period will be changes.

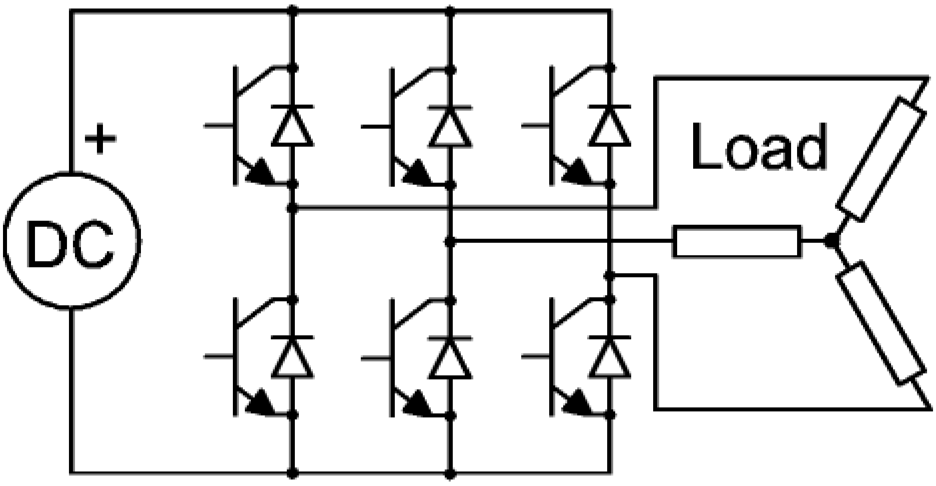

Fig.5. Three phase voltage source inverter.

SPACE VECTOR MODULATION

The final step in the Field oriented control process is to generate pulse-width modulation signals for the 3-phase motor voltage signals. If you use Space Vector Modulation (SVM) techniques, the process of generating the pulse width for each of the three phases is reduced to a few simple equations. In this implementation, the Inverse Clarke's Transform has been folded into the SVM routine, which further simplifies the calculations. Each of the three inverter outputs can be in one of two states. The inverter output can be connected to either the + bus rail or the - bus rail, which allows for 23 = 8 possible states. The two states in which all three outputs are connected to either the + bus or the - bus are considered null states because there is no line-to-line voltage across any of the phases. These are plotted at the origin of the SVM Star. The remaining six states are represented as vectors with 60 degree rotation between each state.

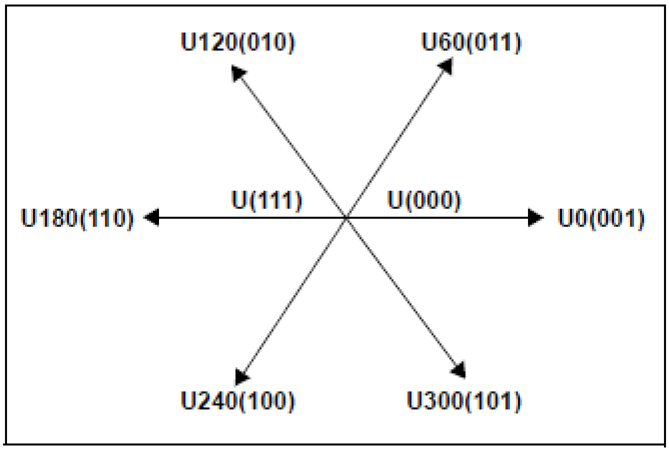

Fig.6. SVM switching states.

The process of Space Vector Modulation allows the representation of any resultant vector by the sum of the components of the two adjacent vectors. U_{OUT} Is the desired resultant. It lies in the sector between U_{60} and U_0. If during a given PWM period T, U_0 is output for T_1/T and U_{60} is output for T_2/T, the average for the period will be U_{OUT}.

T0 represents a time where no effective voltage is applied into the windings; that is, where a null vector is applied. The values for T_1 and T_2 can be extracted with no extra calculations by using a modified Inverse Clark's transformation. If you reverse V_α and V_β, a reference axis is generated that is shifted by 30 degrees from the SVM star. As a result, for each of the six segments, one axis is exactly opposite that segment and the other two axes symmetrically bound the segment. The values of the vector components along those two bounding axes are equal to T_1 and T_2. Which forces symmetry about the center of the period. This configuration produces two pulses line-to-line during each period. The effective switching frequency is doubled, reducing the ripple current while not increasing the switching losses in the power devices.

Phase C	Phase B	Phase A	V_{ab}	V_{bc}	V_{ca}	V_{ds}	V_{qs}	Vector
0	0	0	0	0	0	0	0	U(000)
0	0	1	V_{DC}	0	$-V_{DC}$	$2/3V_{DC}$	0	U_0
0	1	1	0	V_{DC}	$-V_{DC}$	$V_{DC}/3$	$V_{DC}/3$	U_{60}
0	1	0	$-V_{DC}$	V_{DC}	0	$-V_{DC}/3$	$V_{DC}/3$	U_{120}
1	1	0	$-V_{DC}$	0	V_{DC}	$-2V_{DC}/3$	0	U_{180}
1	0	0	0	$-V_{DC}$	V_{DC}	$-V_{DC}/3$	$-V_{DC}/3$	U_{240}
1	0	1	V_{DC}	$-V_{DC}$	0	$V_{DC}/3$	$-V_{DC}/3$	U_{300}
1	1	1	0	0	0	0	0	U(111)

Fig.7. SVM switching state voltage values.

IV.SIMULATION RESULTS

The simulation of a three phase sensor less field oriented control for BLDC drive is done in MATLAB/SIMULINK. The inverter output voltages and currents, motor output parameters can be analyzed through Simulink. Also compare the theoretical analysis and simulation results.

The simulations are implemented in MATLAB in order to justify the necessity and effectiveness of the proposed stabilizing loops. First, the capability to tolerate sudden load change is tested. When the motor is running at 800 rpm, the load is stepped up from 0%to 50% and 50% to 100% of the rated load.

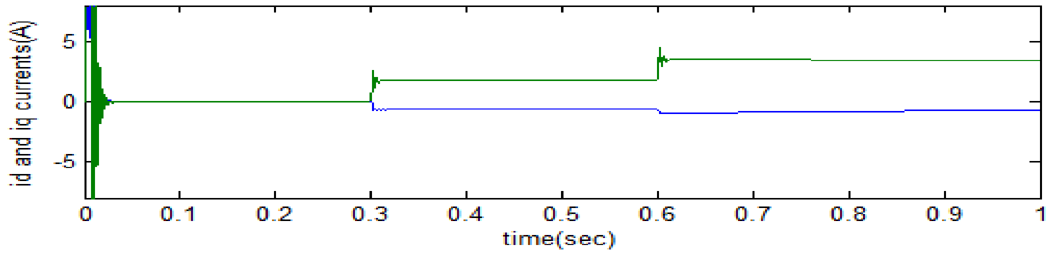

Fig.8 Simulation result for i_d and i_q currents.

The accurate derivation of i_d and i_q is critically important and it depends on precise load angle calculation.

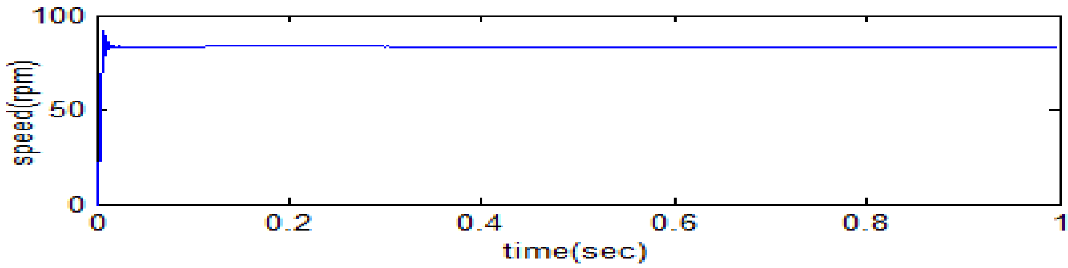

Fig.9. Simulation result for BLDC motor speed.

When the load angle is increased from 0% to 50% of the rated load, the BLDC drive runs at 90 rpm.

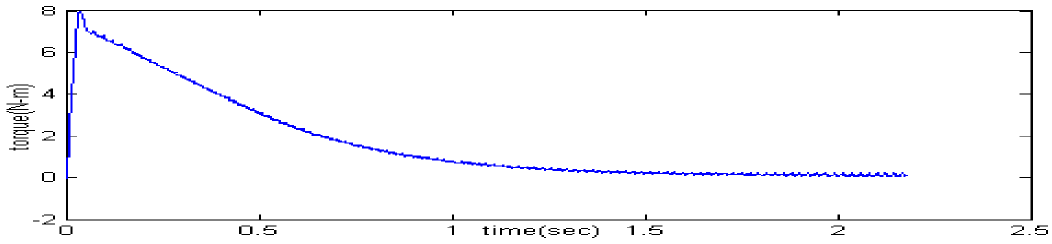

Fig.10. Simulation result for BLDC motor torque.

When the inverter voltage and currents changes, suddenly BLDC motor torque will be varied.

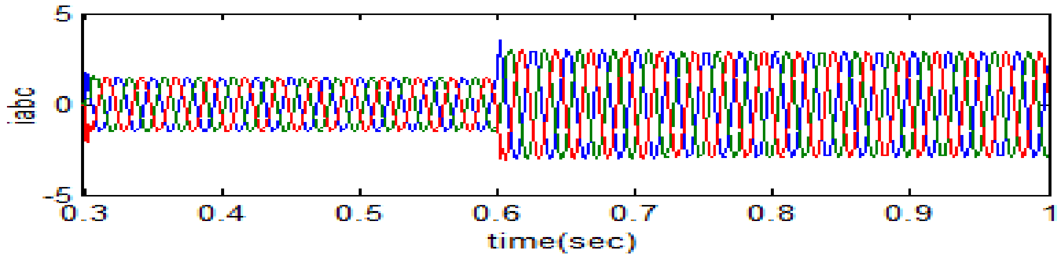

Fig.11. Simulation result for i_{abc} currents.

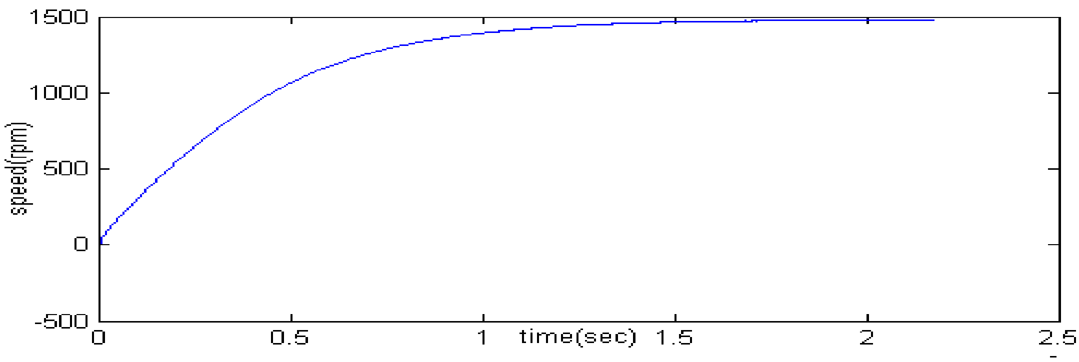

Fig.12. Simulation result for BLDC motor speed.

When the load angle is increased from 50% to 100% of the rated load, the BLDC drive runs at 800 rpm.

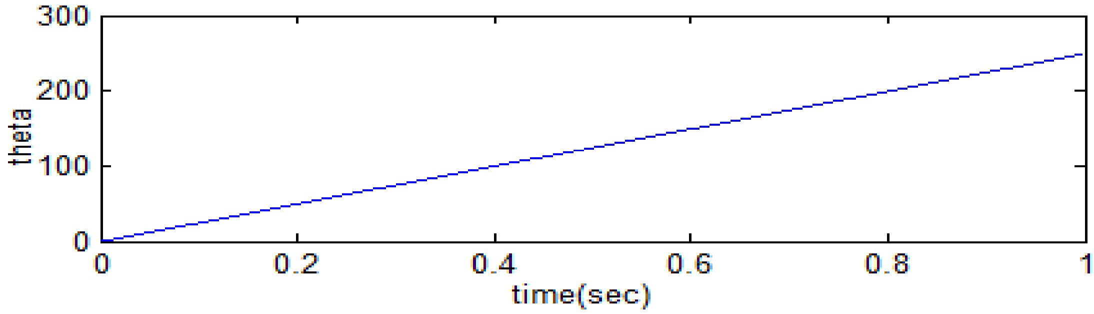

Fig.13. Simulation result for angle theta.

When the d-axis and q-axis currents (i_d, i_q) changes, corresponding rotor angle will be changed.

When the torque generation efficiency is effected by two factors, i_d and i_q currents, MTPA integrated calculations.

V.CONCLUSION

This paper presents a three phase sensor less field oriented control for BLDC motor drives. The proposed closed loop field oriented control not only controls the wide speed ranges it also obtain the maximum torque per ampere (MTPA). This circuit maintains stable operation under very low speed ranges it is most challenging task in sensor less control. Its robustness to machine parameter variation and achieving better control performance without using any speed feedbacks. Robustness and advantages of the proposed closed loop sensor less control circuit are verified through simulation results. The results have been presented and analysed for different speed conditions.

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