IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Vol. 7, Issue 3, March 2020

Modelling and Implementation for Sliding Mode Control of BLDC Motor Drive

P.RamReddy[1], G. Joga Rao[2]

Assistant Professor, Department of EEE, KITS, Huzurabad, Telangana, India[1]

Associate Professor, Department of EEE, RIT, Visakhapatnam, India[2]

Abstract: The sliding mode control technique for permanent magnet brushless DC motor is used to improve its dynamic performance with high accuracy. The proposed novel Sliding Mode (SM) controller method is used drive at all speed levels. The SM controller is the most attractive and simple in modelling for its insensitivity to parameter variations and external disturbances. The validity of the proposed method is verified through simulation. The PMBLDC motor is inherently electronically controlled and requires rotor position information for proper commutation of current. An equation based model for closed loop operation of PMBLDC motor drive is simulated in MATLAB/Simulink. Simulation results show the proposed SM Controller has the advantage of fast response and less steady-state error when compared to that of the conventional PI controller. In this paper the responses of current, speed and torque using SM controller is compared with that of PI controller.

Keywords: Brushless DC motor, MOSFET, Sliding mode controller, PI controller.

I. INTRODUCTION

The BLDC is essentially configured as a permanent magnet rotating part, a set of current carrying conductors. In this respect, it is equivalent to an inverted DC commutator motor, in that the magnet rotates while the conductors remain stationary. In both cases, the current must reverse polarity every time a magnet pole passes by, in order that the torque is unidirectional. In the DC commutator motor, the commutator and brushes perform the polarity reversal. In the brushless DC motor, the polarity reversal is performed by power MOSFETS, which must be switched in synchronism with the rotor position. The MOSFETS being used in configuration of the inverter are operated at standard operation of the BLDC motor. The stator is normally 3-phase star connected. The three-phase star connected of which each commutation sequence has one of the windings energized to positive power current entering into the winding and the second winding energized to negative power current exits the winding and third winding non-energized. Torque is produced by the interaction of the magnetic field produced by the permanent magnets and the stator windings.

II. MATHEMATICAL MODELLING OF BLDC MOTOR

In order to design and develop the control algorithm for electrical drives with BLDC motor, the suitable model still remains the transfer function or the state space. Both models cover only the case of linear time invariant systems which is not the case of BLDC motors. The classical way of analysing the behaviour of the BLDC PM motor is to consider its three voltage phases, in the matrix form also known as stationary reference frame ABC:

$$\begin{pmatrix} v_a & - & v_n \\ v_b & - & v_n \\ v_c & - & v_n \end{pmatrix} = \begin{pmatrix} R_a & 0 & 0 \\ 0 & R_b & 0 \\ 0 & 0 & R_c \end{pmatrix} \begin{pmatrix} I_a \\ I_b \\ I_c \end{pmatrix} + \begin{pmatrix} L_a & 0 & 0 \\ 0 & L_b & 0 \\ 0 & 0 & L_C \end{pmatrix} \begin{pmatrix} \frac{di_a}{dt} \\ \frac{di_b}{dt} \\ \frac{di_c}{dt} \end{pmatrix} + \begin{pmatrix} K_{ea} \\ K_{eb} \\ K_{ec} \end{pmatrix} \omega_r \quad (1)$$

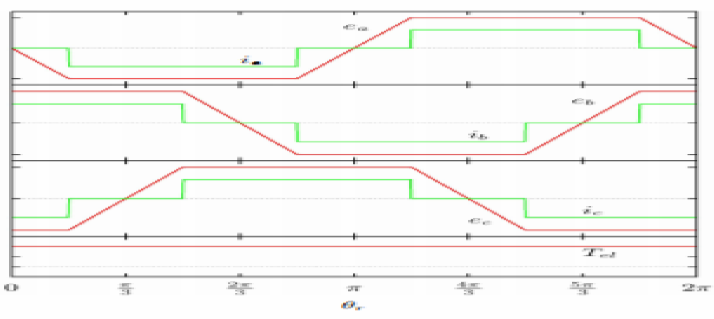

Fig. 1 Trapezoidal waveform of three phase current

Wherev_a, v_b, v_c, i_a, i_b, i_c, R, L are the notations for phase voltages, currents, resistance and inductance respectively. The third term of the sum in (1) represents the back EMFs which are directly proportional to rotor speed (angular velocity) by the constant factors Kea, Keb, Kec. For the star connection of the 3 phases, the nodal voltage is represented by v_n which is not accessible to direct measurements in practice. Rewriting the equation 1 considering only two active phases at a time that is predefined by the inner functionality of the motor, results:

$V_{A=}v_{ap,}v_b$= 0, $i_b = -i_a$, i_c= 0

Vap = $(R_a + R_b)\, i_a + (L_a + L_b)\frac{di_a}{dt} + (K_{ea} + K_{eb})\, \omega_r$

Where $V_{ap}= u \cdot v_s$ is the pulse width modulated voltage supplied to the superior stage of the inverter, with $u \in [0, 1]$. Applying the same procedure for the other two cases of active phases and introducing a convenient average current $\tilde{\iota}(t) = \frac{i_{s}t}{u}$, the matrix form can be replace by one relation in (2).

Vap = $(R_a + R_b)\, i_a + (L_a + L_b)\frac{di_a}{dt} + (K_{ea} + K_{eb})\, \omega_r$ (2)

Where, $R = \frac{2}{3}(R_a + R_b + R_C)$, $L = \frac{2}{3}(L_a + L_b + L_c)$ and $K_e = \frac{2}{3}(K_{ea} + K_{eb} + K_{ec})$.

III. SLIDING MODE CONTROLLER

The sliding mode controller modelling approach involves two distinct stages. The first stage considers the modelling of a switching function which provides desirable system performance in the sliding mode as shown in Fig. 1. The second stage consists of modelling a control law which will ensure the sliding mode, and thus the desired performance, is attained and maintained. With sliding mode controller, the system is controlled in such a way that the speed error in the BLDC motor always moves towards a sliding surface. The sliding surface is defined with the tracking speed error of the motor and its rate of change of variables. The distance of the error trajectory from the sliding surface and its rate of convergence are used to decide the control input to the motor. The sign of the control input must change at the intersection of the tracking error trajectory with the sliding surface. In this way the error trajectory is always forced to move towards the sliding surface. The rotor speed ω_r is given as

$\omega_{r=}\int(\mathrm{Te} - \mathrm{TL}).\,dt$ (2)

The equation (2) can be written as

$\dot{\omega}= (\alpha + \Delta\alpha)\omega + (b + \Delta b)I_a + (c + \Delta c)T_L$ (3)

Where $\alpha = -\frac{B}{J}$, $b = K_t/J$, $c = -\frac{1}{J}$

$\Delta\alpha, \Delta b, \Delta c$ Represents the transient or disturbance values of the machine parameters J, B, Kt respectively

The state variable is defined as

$y=\omega - \omega_{ref}$ (4)

For step changes in speed reference

$y = ay + b\dot{I_a} + a\omega_{ref} + \delta$ (5)

Where the total disturbance δ is defined as

$\delta = \Delta a\omega + \Delta bI_a + (c + \Delta c)T_L$ (6)

The design of the sliding mode controller includes the selection of sliding surface and the control law. Once the system states enter the sliding mode, the system dynamics is determined by the chosen sliding surface and is robust to the disturbances as well as parameters variations. The control law must satisfy the reaching condition and guarantees the existence of the sliding mode.53Since SMC is applicable to the first-order system, the SMC employs the acceleration signal, which is sensitive to the noises.

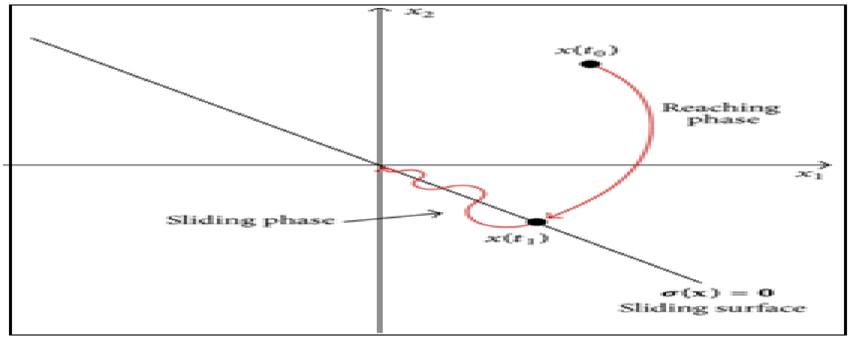

Fig.2The behaviour of system states in sliding mode control.

IV. PI CONTROLLER

PI controller operates the BLDC motor at the set point corresponding to a reference speed. It is important to incorporate a controller in the feedback path. The PI controller contains an outer speed controller and an inner current controller. Accordingly a PI speed controller has been chosen with gain parameters K_p and K_i. The speed of the BLDC motor compared with the reference value and the error in speed is processed by the speed controller.
The output of the PI controller at any instant is the reference torque given by

$$T_{ref} = \left(Kp + \frac{K_i}{s}\right).(\omega_{ref} - \omega_r) \qquad (7)$$

V. BLDC MOTOR DRIVE WITH SLIDING MODE CONTROLLER

The general block diagram of the SM controller drive of the brushless DC motor is shown in Fig. 2.the complete drive system of a BLDC motor consists of a permanent magnet motor fed by a three-phase PWM inverter, rotor position estimation and SM controller. The inverter which is connected to the dc supply feeds controlled power to the motor. The magnitude and frequency of the inverter output voltage depends on the switching signals generated by the hysteresis controller. The state of these switching signals at any instant is determined by the rotor position, speed error and winding currents. The controller synchronizes the winding currents with the rotor position. It also facilitates the variable speed operation of the drive and maintains the motor speed reference value even during load variation and supply fluctuations. The Simulink model of the PI controller and SM controller is shown in Fig. 3.

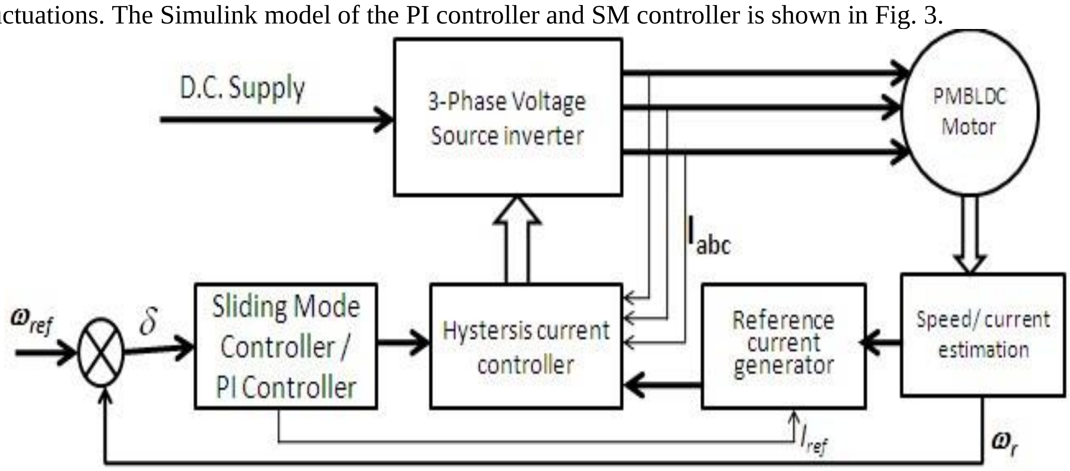

Fig.3Block diagram of BLDC drive with sliding mode controller.

VI. SIMULATION RESULTS

The motor is started at no-load and reference speed is set at 150 rad/sec at no load. Load torque of 1 Nm is applied after 1 sec. The motor is rated at 100 V, 2 Nm and 136 rad/sec as shown in Table 1. The results of BLDC motor with PI and SM controllers are compared. The simulation block diagram is shown in Fig. 4. The variation of current, speed, and torque are shown in Fig. 5 and Fig. 6.

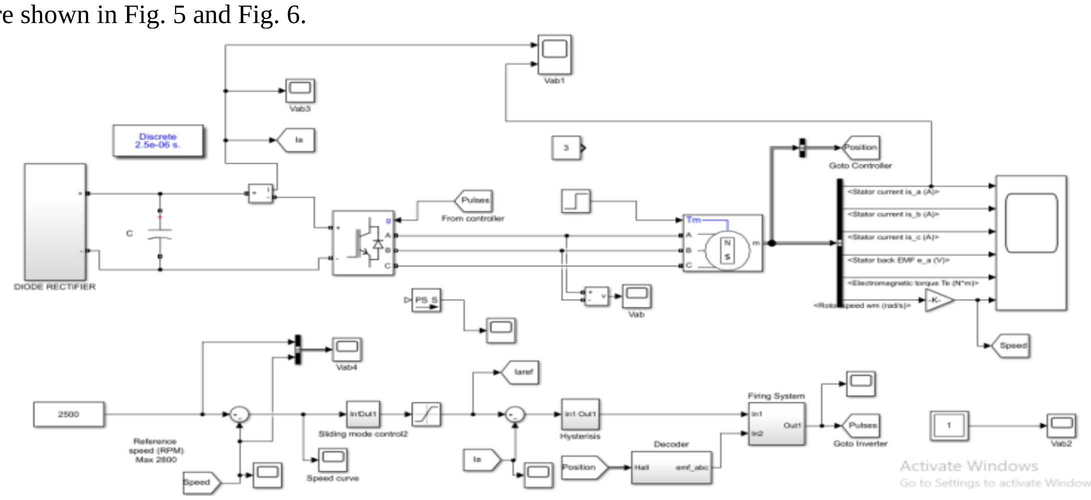

Fig. 4 Simulation model of PI controller and SM controller.

 DOI 10.17148/IARJSET.2020.7305

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
Vol. 7, Issue 3, March 2020

6.1 SPEED ,TORQUE, 3- PHASE CURRENT OF THE BLDC IN THE SM CONTROLLER

The proposed SM controller is used and the appropriate characteristics are found. While we can see that the performance characteristics are less when compared to PI controller.

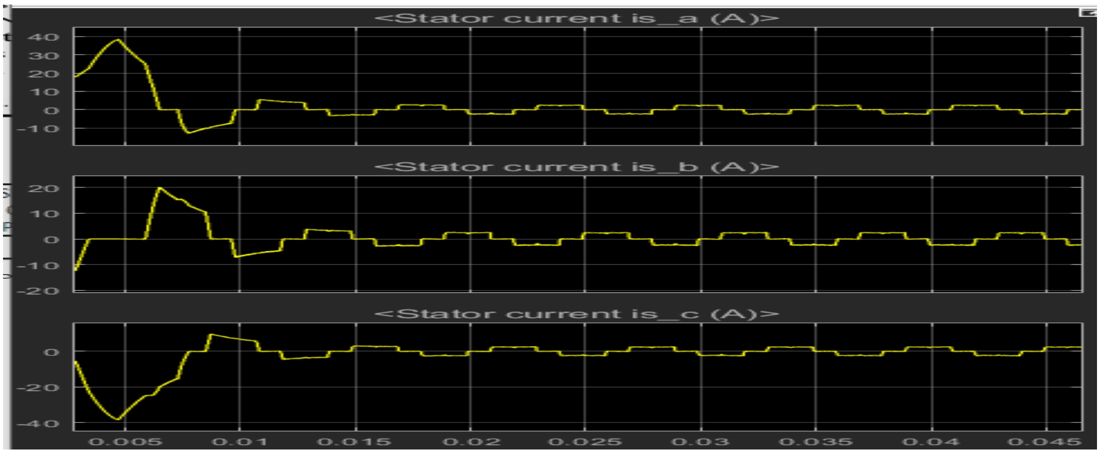

Fig.5 (a) Three phase current of a BLDC motor. SM controller

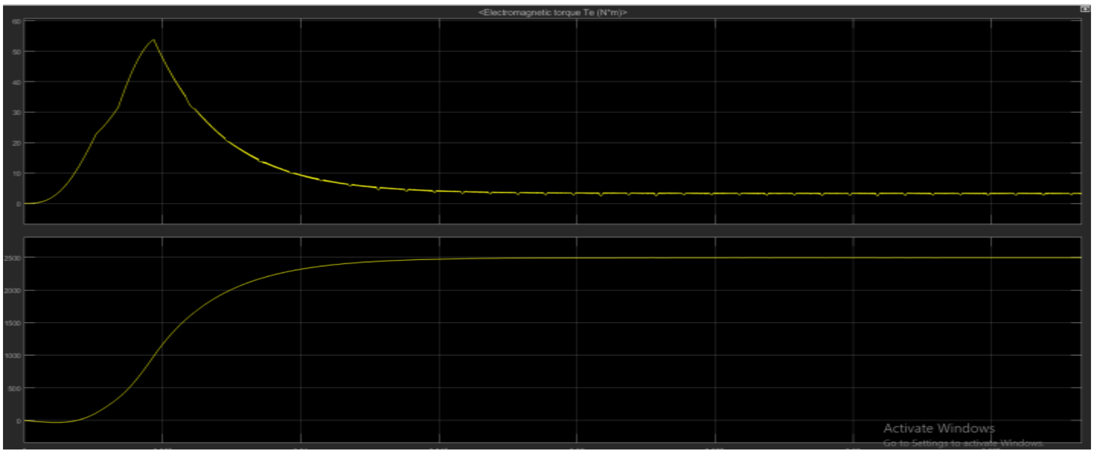

Fig.5 (b) speed and torque of bldc motor in SM controller.

6.2 SPEED, TORQUE, 3- PHASE CURRENT OF THE BLDC IN THE PI CONTROLLER:

Where we can the speed and torque are rippled when compared to the SM controller.

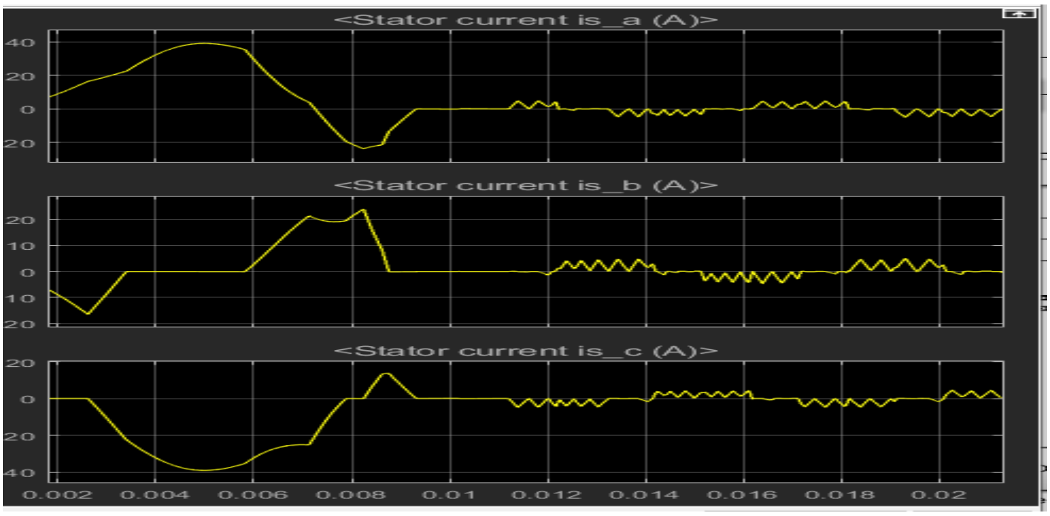

Fig.6 (a) Three phase current of a BLDC motor PI controller.

IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Vol. 7, Issue 3, March 2020

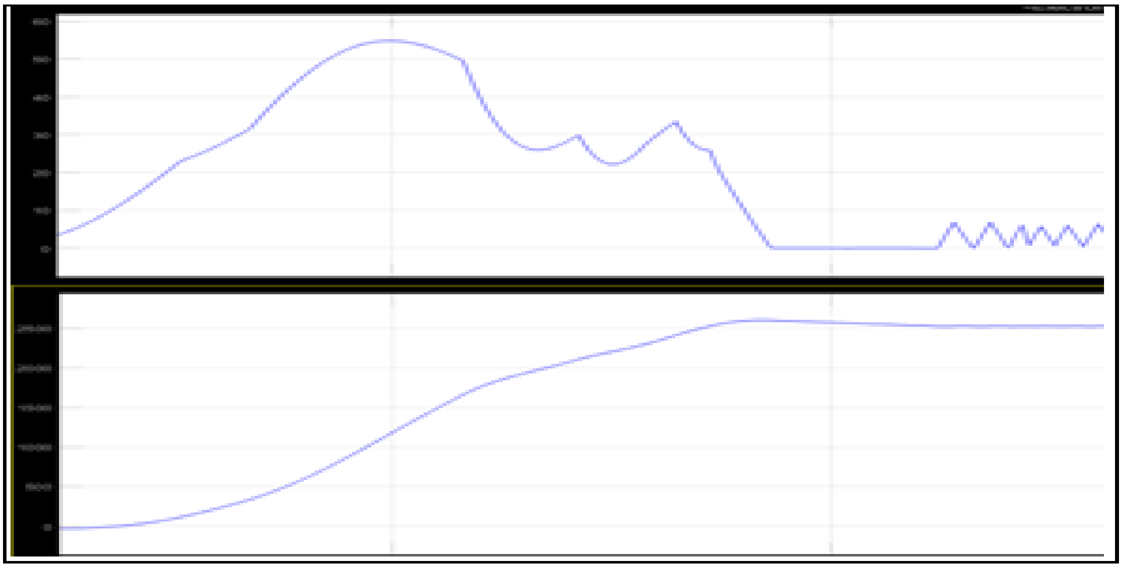

Fig.6 (b) speed and torque of bldc motor in PI controller.

VII.CONCLUSION

In this paper the sliding mode controller form BLDC motor was modelled and analysed. It's organized so as to apply the SM control technique for BLDC motor. It also gives good trajectory tracking performance. The responses of current speed and torque with SM controller are superior then with PI controller. The SM controller is simulated under transient conditions and a comparative study of the results with that of PI controller has been presented and proved that SM controller has better performance in all aspects.

REFERENCES

[1]. S. M. Metev and V. P. Veiko, *Laser Assisted Micro technology*, 2nd ed.,R. M. Osgood, Jr., Ed. Berlin, Germany: Springer-Verlag, 1998.
[2]. Miller T.J.E and Hendershot Jr. J.R (1994), *Design of brushless Permanent Magnet Motors*, Magna Physics Publishing and Clarendon press, Oxford.
[3]. Pragasen Pillay and R. Krishnan, *Modeling, Simulation, and Analysis of Permanent Magnet Motor Drives, Part-II: The Brushless DC Motor Drive*, IEEE Trans.on Industry Application, Vol.25, No.2, pp.274-279, March/April1989.
[4]. Tae-Hung Kim and Mehrdad Ehsani, *Sensorless Control of the BLDC Motors From Near-Zero to High Speeds*, IEEE Trans.Power Electronics, Vol. 19, No. 6, November 2004.
[5]. Vadim I. Utkin, "Sliding mode control design principles and applications to electric drives," IEEE Transactions on Industrial Electronics, vol.40, no.1, pp23-36, February 1993.
[6]. Hailong Song, Young Yu, Ming Yang , Dianguo Xu, A Novel SMC-Fuzzy Speed Controller for Permanent Magnet Brushless DC Motor, IEEE, pp.281-285, 2003.
[7]. Jessen Chen and Pei-Chong Tang, *A sliding mode current control scheme for PWM brushless DC motor drives*, IEE Proc.-Electr. Power Appll,vol.14, no.3, pp.541-551, May, 1999.
[8]. Xia changliang, "BLDC motor control system," M. Science press. Feb.2009. pp.80-82.
[9]. Yuan zhao hui, Lin wei zhong, "Fuzzy Sliding Mode Control Based on Genetic Algorithm for Brushless DC Motor, " Small & Special Electrical chines, Feb.2009, pp. 43-46.
[10]. J. Chen and P.-C. Tang, "A sliding mode current control scheme for PWM brushless DC motor drives," *IEEE Trans. Power Electronics*, vol.14, no.3, pp. 541–551, May, 1999.
[11]. G.Joga Rao, DVN Ananth "Performance Enhancement of PMBL DC Motor Drive by Multi-Carrier Modulation Technique" International Journal of Innovative Technology and Exploring Engineering (IJITEE), volume-8 Issue-7, May- June-2019
[12]. Chee-Mum Ong, Dynamic Simulation of Electric Machinery using MATLAB/Simulink, 1998.
[13]. G.Joga Rao, An Advanced Bldc Drive System For Industrial Application With Fewer Switching Components, International Journal Of Latest Advances In Electronic And Electric Engineering (Ijlaeee), Issn: 2319 – 8885, Volume-3, Issue-2, pp. 110-116, 2014